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WIND PROFILE CLIMATOLOGY OF NEW ORLEANS, LOUISIANA

by

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ABSTRACT

The prominent climatological features of the tropospheric wind field at New Orleans, Louisiana, have been analyzed in terms of wind direction and wind speed. For the purpose of appraising the physical properties of the acoustical far field at the Mississippi Test Facility within the adjacent environment of New Orleans, the directional parameter of the wind field was investigated in particular depth. Besides the mean profiles of wind direction, the mode profiles were derived by means of a new method developed by Dr. Essenwanger, which is presented in an appendix to the report.

Both the wind direction profiles, in terms of mean and mode, and the mean scalar wind speed profiles are presented for the whole year, the four seasons, and the individual months. Also, the annual profiles of various time periods of the day are provided for both wind direction and wind speed.

Multimodes of the wind direction profiles appear typical in the planetary boundary layer (approximately surface to 2500-meter height), mostly with surface azimuths of North and South. During the summer months, the middle troposphere is covered by a remarkably complex pattern of multimodal wind direction profiles. Also, the annual wind direction profiles of various time periods of the day show at least a bimodal configuration in the upper troposphere, above the jetstream level.

The mean wind speed profiles exhibit the typical tropospheric pattern with the speed maximum at the subtropical jetstream level of about 12 kilometers. These monthly profiles indicate a systematic dispersion of speed magnitudes, increasing toward spring. The maximum of the mean wind speed at New Orleans, Louisiana, occurs during the period of March, with a value of 83 meters per second, and at a height of 12 kilometers. However, the mean speed profiles of the summer months show remarkable uniformity, with considerably lower wind speed magnitudes, not exceeding a maximum value of 30 meters per second (13-kilometer altitude).

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I. INTRODUCTION

Wind climatology has become significant in various fields of technology. The prominent implications of wind effects in an altitude range close to the ground (planetary boundary layer) pertain to three major areas of technological application:

1. Building structures,

2. Airport layout and operation, and

3. Annoying effects to inhabited areas.

In area 1, building structure, the main factor of influence is primarily constituted by the strength of wind flow or wind speed, but in cases 2 and 3 the dominant component of wind effects is represented by wind direction. In airport wind effects the probability of prevaling wind directions determines optimal takeoff and landing operations of aircraft. But, more recently, airport operation also must consider a wind-dependent effect which is an inherent feature of the third category ot wind-affected technological phenomena, whose main constituents are noise and air contamination such as smoke and fumes. The common observer is usually aware of the wind influence, in contrast to the case of no wind, on the annoyance effects of the latter group of physical occurrences. However, the strong dependence, in particular, on wind direction of these annoyance effects is sometimes overlooked. Since aircraft noise (turbo-jet noise, sonic-boom bangs) is a commonly recognized bother of modern conveyance technology, a more recent public acoustical disturbance is the jet-generated noise of large rocket power plants, particularly during static test firings of these super-sized energy generators.

It has been well analyzed [1-3] that the distribution of wind direction frequencies around the windrose prominently controls the frequency of sound propagation into certain directions referred to the sound source, as well as the distribution of sound intensity as a function of distance from the sound source. As a consequence, for the appraising of sound propagation phenomena, the three-dimensional field of the thermodynamic sound velocity and the three-dimensional wind field always have to be properly superimposed to assess the total resultant effect of the instantaneous sound propagation qualities of the atmosphere. Depending on the dimensions of the sound field (radial distance from sound source) to be considered, proportional height scales of the vertical sound velocity profile have to be taken into account. With the enormous sound energy levels of space rocket boosters now present, the annoying noise effects reach out to radial dimensions of hundreds of kilometers. For these travel distances of the sound energy, the sound velocity profile and thus the vertical wind profile have to be studied beyond the planetary boundary layer. Practically, the wind field throughout the whole troposphere has to be analyzed, which is bounded by the tropopause at an approximate altitude of 15 kilometers in the southeastern United States, being situated in subtropical latitudes.

Similar considerations hold for the wind influence on the contamination effects; the more buoyancy energy a plume of smoke or of fumes contains, the higher are the levels of the vertical wind profile to be taken into account.

From the outlined physical concepts, the wind field around New Orleans, Louisiana, was analyzed with particular emphasis on the qualities of the vertical wind direction profiles. The practical value of this climatological wind field analysis at this specific location becomes evident from the severe noise annoyance problem caused by the nearby Mississippi Test Facility of NASA. Simultaneously, this analysis of the wind field at New Orleans represents a working example of the novel concept of cumulative frequency distributions of periodic parameters such as wind direction [4].

II. METHOD OF ANALYSIS

The wind parameter as a vector quantity has long since posed the problem of adequate presentation for analytical and numerical purposes. Conventionally, the method used has been splitting the wind vectors into Cartesian (North and East) components and eventually deriving the "resultant wind" as the average square root of the summed squares of the wind component sums [5]. However, this component concept is not very amenable to statistical treatment of the directional properties of the wind quantities. In general, the wind direction is a physical quantity obstinate to conventional procedures for obtaining frequency distributions, because of its periodic characteristics. Since previously established methods of wind data processing for statistical purposes appear quite refined, and thus laborious and costly [4, 6], a more straightforward, compromising method was designed which utilizes the mean and the mode of wind direction as two characteristics of frequency distribution. The wind speed, which is represented by the magnitude of the wind vector, is naturally less complex in expressing statistically the properties of the frequency distributions. Therefore, the mean value was chosen only to provide information about the wind speed.

The mean value of the wind direction, as computed according to the method of Essenwanger [6], may properly serve as a characteristic in case of unimodal distributions. However, the mean and mode values diverge in the case of multimodal distributions. Primarily in summer, and at lower altitudes, frequency distributions of wind-direction exhibit multimodal features. Therefore, the mode characteristics had to be included into the presentation of the wind direction profile, and more than one mode is incorporated into the data compilation. The method of determining the mode profiles, which was applied in this investigation, is presented in the Appendix. The method is specifically designed to machine computations. The three main topics of this novel mathematical procedure of determining the modes of wind direction frequencies comprise the following features:

1. The sorting of frequencies of occurrence into classes by assigning "class symbols" (equal," "larger," or "smaller") with reference to the adjacent class, beginning with the class of minimum frequency.

2. The establishment of a criterion of "significant progress," which is supposed to characterize the significant differences between frequency classes. The significance parameter is shown to depend on the sample size, the confidence limit, and a parameter controlling the weight of minor modes.

3. The determination of the modes proper, which hinges on the sequence of class symbols as explained under the first topic. Further, the optimization of the number of frequency classes is outlined.

It is self-evident that the random fluctuations of the frequency distributions ought to be eliminated in the process of determining the mode, or several modes. Also, insignificant modes are to be suppressed. Both features of data processing have been incorporated into the machine computing method presented in the Appendix.

The frequency distributions of wind speed generally occur in a unimodal fashion. For the present purpose, the listing of the mean values of wind speed may suffice, although median, mode, and mean values usually differ to some extent.

III. SOURCE OF DATA

The wind data presented in this statistical analysis derive from Pibal observations, performed by the U. S. Weather Bureau, Station No. 12916, at New Orleans, Louisiana. The field measurements were processed at the National Weather Record Center (NWRC), Asheville, North Carolina, and tabulated in the format of the "Wind-Aloft Summary" (Revised Format - January 1, 1963). This format presents the wind data in terms of number-of-occurrence for 16 points of compass, plus calms, and in wind speed intervals of 5 meters per second. These frequency classifications are given at the surface, at 150, 300, and 500 meters of height, then every 500 meters of altitude increase up to 3000 meters and thereafter at every 1000-meter altitude interval to the ceiling height of the Pibals, which in single cases extends to an altitude of 25 kilometers (= 31 altitude levels).

The altitude levels of recording, quoted above, have been adopted for the computation of statistical parameters.

Further, the "Wind-Aloft Summary" provides the average scalar wind speed, plus its standard deviation. The data are subdivided into the following time periods of the day:

1. All hours of the day

2. 03:00 Z

3. 06:00...09:00 Z

4. 15:00 Z

5. 18:00...21:00 Z.

These daily time periods of observation apply to the annual, seasonal, and monthly data sets. The data records comprise the period of January 1949 through December 1959 for the daily observational periods 1, 3, and 5. For the daily periods 2 and 4, the length of record is limited to the period of January 1949 through August 1950. The total number of observations during the ten-year period of record starts with 8352 single data at the surface, and decreases slightly to 7841 data at a 1000-meter height. The 5000 mark of observations is passed at an elevation of 4000 meters. A thousand observations are still available at 10 kilometers of altitude. This usual decrease of observations with altitude may cause some bias in the mean wind speed, the average value being on the low side above 10 kilometers.

IV. CHARACTERISTICS OF WIND DIRECTION PROFILES

Figures showing these data are at the end of this report. Seasonal wind direction profiles are represented in Figures 1 through 4, monthly profiles in Figures 5 through 16. Figure 17 depicts an all-hour annual wind direction profile, and the following four (Figs. 18-21) represent specific annual time integral periods. Figure 28 is the flow chart for determination of modes of wind direction distribution.

A. Seasonal Wind Directions Within Troposphere

The characteristic features of the wind direction profiles[1] at New Orleans, Louisiana, during any time of the year, are more clearly recognized at large by viewing the seasonal profiles first. Figures 1 through 4 indicate a rather distinct behavior of the wind-direction patterns below (i.e., in the planetary boundary layer) and above (i.e., in the tropospheric wind field) the altitude level of 2500 meters. During the seasons of spring, fall, and winter, a fairly well defined behavior of the wind direction profile with unimodal features above a 2500-meter altitude can be seen. For the altitude range above 2500 meters, these directional profiles exhibit almost identical magnitudes of mean and mode. Another characteristic of the wind direction profiles during spring, fall, and winter is the nearly constant prevailing direction, near West, above the quoted reference level of the 2500-meter altitude. This fact indicates that the atmospheric flow at New Orleans above the planetary boundary layer pronouncedly participates in the general winterly western circulation pattern.

However, during the summer season (Fig. 2), the wind direction profile at New Orleans exhibits a wide variety of features both in the lowest four kilometers of altitude and above a 6-kilometer height. At these higher altitudes, the summer profile splits into as many as three modes between about 9 and 13 kilometers of altitude. These summer modes range from South to approximately ENE, turning through North. In this altitude interval the mean does not coincide with either one of the modes further and stretches from West (through North) to East. But even the summer profile shows a certain "transitional" regime at an altitude between 4 and 5 kilometers, in which mean and mode essentially coincide, and indicate a remarkable shift of wind direction from SE (through South and West) to North within an altitude layer of no more than 2 kilometers in height.

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[1]An aerological profile is a variation of atmospheric parameter as a function of altitude.

B. Seasonal Wind Directions Within Planetary Boundary Layer

Another wind direction characteristic of the planetary boundary layer (0-2500-meter altitude range) is that somewhat swift shifts are recognizable during all four seasons.

Winter and Spring Wind Direction Profiles. During winter (Fig. 4) and spring (Fig. 1) the wind directions in the planetary boundary layer rotate clockwise with altitude, starting with the mean at ESE and advancing to WSW at a 2500-meter altitude. The winter mode profile essentially follows the mean profile of that season. However, in spring two modes are present in the planetary boundary layer, on top of each other. The lower of these two turns clockwise from SSE to North, reaching this direction at a height of 1 kilometer. This mode then swings back to WNW at about 2500 meter altitude, where it combines with the first mode, staying as a uniform mode throughout all of the troposphere.

Fall Wind Direction Profiles. The wind direction pattern of the planetary boundary layer during the fall season (Fig. 3) is to a large extent an opposite case to the profiles during winter and spring. Both the mean and mode profiles start close to NE, and swing clockwise to ESE with a rather sharp turn to a distinct reversal point at the upper edge of the planetary boundary layer (approximately 2500-meter altitude). From there, a swift reversal turns the profiles counterclockwise back to West, at a 3000-meter height. Very strong directional wind shears must be involved in this behavior, because the directional reversal of almost 200 degrees occurs within an altitude interval of only 500 meters. The tropospheric directional profile, then, remains quite consistent between WNW and WSW throughout the whole troposphere, as explained before. For affirmation, it is quoted again that the directional mode profile in the fall season follows closely the mean profile throughout the planetary boundary layer.

Summer Wind Direction Profiles. The summer profiles of wind direction within the planetary boundary layer display a structure about as complex as in the higher troposphere (above 6 kilometers; Fig. 2). The mean profile starts out at about South, with the typical trend of a right turn with altitude ("EKMAN-spiral"). However, at 1 kilometer in height a distinct profile inversion occurs slightly to the West of South, beyond which the mean profile turns to a direction somewhat East to SE at a 3-kilometer altitude.

The wind direction mode within the planetary boundary layer during the summer season starts at South, then splits into two branches from 500 meters upward. At an altitude of about 2000 meters, one branch of the mode swings from SSW in a consistent turn through the lower third of the tropospheric altitude range with a total change of wind direction of 160 degrees, toward North.

C. Monthly Wind Direction Profiles

The phenomenological description of monthly wind direction profiles at New Orleans, Louisiana, shall basically be presented in terms of a comparison with the corresponding seasonal profiles.

Winter Months: December, January, February. The winterly mean wind direction profiles (Figs. 5, 6, and 16) very closely resemble the mean profile of the winter season (Fig. 4) above the planetary boundary layer (3-kilometer height). The same fact can essentially be stated about the profile modes. Almost the only deviation of the monthly profile modes from the seasonal modes above the planetary boundary layer occurs within the lower half of the troposphere (4- to 10-kilometer altitude range), where a kind of oscillation with height around the seasonal mode can be seen. However, the amplitudes of these directional variations hardly exceed 10 degrees to either side of the seasonal mode.

Within the planetary boundary layer, the mode profile of the winter months splits two branches, contrary to the seasonal mode. Through all three winter months, one of the modes starts at the surface in the SSE to South directions. In December the second mode starts at about SW, and in January at North. In February actually a unique mode prevails at the surface (approximately SSE), and the split into two modes does not occur beneath a height of above 200 meters. Above that altitude, the second mode turns swiftly through West toward NNW, at about a 500-meter altitude. From there, the westerly mode swings back to almost West, where it joins the "southerly" mode at a height of about 1200 meters.

Spring Months: March, April, May. The wind direction profiles of the spring months of March and April (Figs. 7 and 8) indicate basic similarity with each other as well as with the consolidated seasonal profile for spring (Fig. 1). Typically, the mode profiles of both quoted months consist of two branches in the planetary boundary layer, starting at the surface at South and around North. The two branches combine around WNW and at an altitude of 2000 meters in March, and at 4000 meters in April. Above these altitudes of merging modes, the profiles follow the seasonal mode profile (Fig. 1) in both March and April. The mode profile then stays consistently between West and WNW throughout the troposphere.

The mean wind direction profile of May (Fig. 9) basically coincides with the seasonal mean profile as well as the mean direction profiles of March and April. The footpoint of the mean profile of May is located at about SE, quite close to the footpoint of the seasonal mean profile (Fig. 1). The modal direction profile of May exhibits features somewhat different from the modal profiles of the planetary boundary layer during March and April. The May modal profile starts at South with a single mode and does not split until a height of about 1500 meters. One mode then climbs, with only small directional fluctuations, up to a 4000-meter altitude, whereas the other mode gradually turns to WNW (about 2500 meters height) and then joins the "upper" mode at West (about a 5000-meter altitude). From there upward, all May profiles and seasonal profiles of wind direction basically coincide at directions between West and WNW throughout the troposphere. The mode profile of May oscillates with amplitudes not larger than 10 degrees around the consistent westerly mean wind direction throughout the troposphere of the spring season.

Summer Months: June, July, August. As has been pointed out previously, the wind direction profiles at New Orleans during any of the three summer months exhibit a profused pattern. However, a characteristic common configuration is discernible in both the mean and mode profiles within the intermediate altitude range between about 2 and 5 kilometers. All directional profiles of June (Fig. 10) and July (Fig. 11) show, within the designated altitude range, a far-stretched turn of the wind direction through a range of about 320 degrees starting from East and proceeding clockwise around the windrose, through North, to about ENE. Most remarkably, during August (Fig. 12) this wide-range turn of the wind direction proceeds counterclockwise, starting at about SE (mean profile) and turning through East, North, West, and South almost back to SE, that is, a turn of nearly 360 degrees. This large change in wind direction appears as a break from the general pattern, as this counterclockwise turn lasts from August to November, indicating a typical feature for this period of the year. The altitude range covered by this turn of wind direction reaches to a height of 10 kilometers. In the mode profile of August, this extended directional turn also starts just above the planetary boundary layer, has a brief setback (about 20 degrees) between 5 and 7 kilometers, and then proceeds through North and West toward South at a 9-kilometer height.

In the planetary boundary layer of the summer months (Figs. 10-12) the directional wind profiles generally show pattern alternating with height. In June (Fig. 10) and July (Fig. 11) both the mean and mode profiles alternate approximately around SSE by as much as plus or minus 50 degrees, i.e., over half a quadrant. The very lowest levels of the directional profiles indicate a clockwise turn from the surface point (between South and West in June and July, around East in August), but already below 1 kilometer the wind directions swing back in a counterclockwise turn, then continue with quasi-oscillations of direction with progressing altitude. The mode profiles of the planetary boundary layer of June and July split very close to the surface into two branches, of which one always differs significantly from the mean profile, the other one staying close to the mean profile.

In August the planetary boundary layer wind directions show one mode, starting at about East with a clockwise turn to ESE, whereas the mean profile has a stronger counterclockwise turn toward North (reached at a 500-meter height) and then swings back almost to SSE (attained at a 1000-meter altitude). From there, the large, 360-degree counterclockwise swing through the lower two-thirds of the troposphere sets on, as described in the previous paragraphs. The difference of the wind direction profiles of June and July, versus those of August, appears as a remarkable feature of the summer situations of the windfield at New Orleans. These facts indicate the necessity of a larger amount of detailed information for adequately covering the lack of uniformity of wind direction patterns during the summer season. For these strongly alternating profile patterns, the mean profiles lose significance to a considerable degree.

Fall Months: September, October, November. The wind direction profiles of the three months of fall at New Orleans (Figs. 13, 14, 15), exhibit features which individually differ from each other.

Generally, in September (Fig. 13) both the mean and mode wind direction profiles show configurations which are reflected in the corresponding seasonal profiles of fall. The mean profile is virtually composed of two arcs with opposite orientation of the (horizontal) axes of symmetry. The lower arc, with its axis oriented from East toward North, stretching from the surface to almost 4 kilometers, starts at ENE and swings through ESE back to NE at the indicated height. The wider, upper arc, with its axis pointing clockwise (from West toward North), runs from NE through North toward almost West, reaching WNW first at an altitude of about 7 kilometers. The mean wind direction of September then remains fairly steadily close to West. Finally it starts at about a 13-kilometer height, returning toward North and reaching it at approximately 17 kilometers.

Contrarily, the wind direction mode profile of September starts at the surface with two branches, namely at NE and South. These two branches combine to a single one at about ENE in a 3-kilometer altitude. From there on, the mode profile follows the trend of the mean direction profile, remaining in a single mode toward WSW (attained at 11 kilometers). This section of the mode profiles stays at about the same direction up to 13 kilometers.

At this point, the mode profile of September again splits into two branches, one of which remains between WSW and WNW, terminating at 17 kilometers. The other mode branch covers a turn of about 250 degrees, running through North and East toward SE, which is attained at an altitude of 16 kilometers. From there this branch of the mode profile terminates with a swing back to NNE, reached at a height of 17 kilometers.

The wind direction profile characteristics of October at New Orleans (Fig. 14) also show a general resemblance to the seasonal wind direction profiles of this station. A counterclockwise turn of about 160 degrees within the planetary boundary layer prevails as a general trend of both the mean and mode profiles. This turn starts at the surface at NE and ends at about West in approximately a 3000-meter altitude. However, the direction mode profile of October splits into two branches right at the surface. Its easterly branch turns from NE toward SE within the planetary boundary layer, and terminates at about 2500 meters. The northerly branch of the direction mode profile in the planetary boundary layer again splits into two branches at approximately 1500 meters. The primary component of the two branches features a turn of 75 degrees to West (3000-meter height), and joins the mean wind direction profile at approximately NW in a 4000-meter altitude. The secondary branch of the mode profile turns faster than the mentioned primary one to about SW, which is reached at a height of 3000 meters, and terminates at WSW in a 4000-meter altitude.

Throughout the troposphere (i.e., above 2500 meters), both the mean and mode wind direction profiles of October stay fairly close to West, featuring a zigzag turn from West through NW, and back to West, within the lower 3000 meters of the troposphere. The mode profile of the troposphere branches off shortly with a secondary component, at about a 10-kilometer altitude, and produces a zigzag turn toward SW (about 500 meters above the branch-off point), and swings back to about West, at a 11.5-kilometer height, where it terminates.

Finally, the November wind direction profiles (Fig. 15) exhibit a more general resemblance with the January profiles, except for the counterclockwise turn. Thus, this wind direction profile indicates a further tendency of a break towards winter conditions. The November profiles evidence fewer irregularities than those of September and October. Within the planetary boundary layer, the mean profile of November starts at about ENE on the surface. After an initial swing toward almost East (about a 300-meter height), it rapidly turns through North to almost West, being reached at a 1000-meter height. The direction mode profile, however, starts with two discrete branches at the surface, with initial directions of South and NNE. These two branches meet at NW in a 2000-meter altitude. The mode profile then joins, with a transition from NW toward West, at an altitude of 3000 meters.

For the tropospheric altitude range, from 3000 meters upward, both the mean and the mode wind direction profiles of November exhibit a slant from about West toward WSW, and terminate almost at West in a 15-kilometer altitude.

D. Annual Wind Direction Profiles

Although the annual profile comprises the combination of various regimes and thus smooths seasonal features, the larger volume of annual wind data permits a breakdown into separate populations for various hours of the day. Thus annual statistical wind direction presentations for the following periods of the day were prepared:

1. All hours of the day (= 2 through 5 combined)
2. 03:00 Z (21:00 CST, local)
3. 06:00...09:00 Z (00:00...03:00 CST, local)
4. 15:00 Z (09:00 CST, local)
5. 18:00...21:00 Z (12:00...15:00 CST, local).

The grouping of the annual wind data populations into the indicated time periods provides an insight into the eventual existence of significant and characteristic differences between the features of wind direction profiles of various periods of time of the day, irrespective of the previously described seasonal profile trends.

Annual Wind Direction Profiles of All Hours. In the class of annual wind direction profiles comprising all time periods of the day (Fig. 17) three distinctive regimes are evident in both the mean and mode profiles. In the lowest portions of the profiles, from surface to about 3000 meters, the wind directions exhibit a strong clockwise turn of direction with height. In the case of the mean profile, this turn ranges over 180 degrees from East through South toward West. The mode profile, in the same lowest stratum, consists of two separate branches. The more southern branch of the two starts exactly at South and joins the mean profile at 4000 meters at an azimuth slightly north of West. The northerly branch of the mode profile starts at the surface close to NNE, and swings with a 280-degree clockwise turn from North, at a 1000-meter altitude, through South toward West, combining with the southerly mode branch at 3000 meters.

The middle portion of the wind direction profile for all hours of the day exhibits itself within the altitude range from 3000 to 14,500 meters. The wind directions are remarkably steady in this extended height regime, and center around West with only minor fluctuations. The mean profile stays evenly about 10 degrees north of the mode profile, which holds an azimuth of strictly West.

The third uppermost regime of the annual wind direction profiles for all hours of the day covers the altitude range from 14.5 to 21.5 kilometers. Both mean and mode profile essentially show a counterclockwise turn from West back to East. The mean profile takes a limited, clockwise swing of 50 degrees, back from about West to NNW in the altitude range from 14 to 18 kilometers. Above this height, the mean profile exhibits a rapid counterclockwise turn of 290 degrees, thus reaching NE at an elevation of 21 kilometers, going there from NNW through West, South, and East. Within the same altitude range (i.e., 14.5 to 21.5 kilometers), the mode profile splits right at the lower range limit into two branches, of which one remains essentially at its original direction of West, about which it oscillates only by plus or minus ten degrees up to 21.5 kilometers. However, at an 18-kilometer altitude, a secondary branch splits off and turns from West toward SSE within an altitude increase of 2000 meters (termination of branch at a 20-kilometer height). The eastern branch of the mode profile, in the altitude range of 14.5 to 21.5 kilometers, springs off from the middle part of the mode profile at an elevation of 14.5 kilometers, turning rapidly from the western direction counterclockwise toward East, which is attained at an altitude of 15 kilometers. From there upwards to a terminating height of 21 kilometers, the eastern mode branch stays East within about 10 degrees of directional variation.

Annual Wind Direction Profiles at 03:00 Z (21:00 Local). The annual mean profile of wind directions of the early night hours (Fig. 18) resembles the annual mean profile of all hours of the day in the lower and intermediate altitude regions (surface to 5000 meters, and 5 to 18 kilometers, respectively). This is not merely a result of a dominance of the 03:00 Z-observations.

The mean profile starts at about SE at the surface, and turns clockwise towards West which is attained at an elevation of 4500 meters. After a gradual recession of about 10 degrees, with its inflection point at 9000 meters, the mean profile takes a parabolic, clockwise turn with height. This profile terminates at 18 kilometers slightly off the direction of NNW.

The mode profile of wind direction has in the quoted surface region also the tendency of a clockwise turn from about SE (surface) WNW (4 to 5 kilometers). While this mode branch terminates at 5 kilometers, the main mode branch splits off from the described surface branch at 1500 meters and climbs to 7000 meters with a clockwise turn from SSW toward West. The strict western direction is maintained by this mode branch to an elevation of 15 kilometers. At this altitude, a second split of the mode profile occurs, with one branch essentially remaining at West and terminating at an elevation of 18 kilometers. The second mode branch above 15 kilometers experiences a rapid clockwise turn of 165 degrees from West through North and beyond ENE. This large turn affects a prominent directional gradient, since it occurs within an altitude range of only about 2000 meters.

Annual Wind Direction Profiles at 06:00 to 09:00 Z (00:00 to 03:00 Local). Only a limited amount of wind direction data is available for the three-hour time period after midnight (Fig. 19). The latitude range covered by wind data is especially restricted to the lower half of the troposphere, and the wind direction profiles terminate between 8000 and 9000 meters. Hence, no evaluation for higher levels could be presented.

The mean profile of wind direction begins at the surface between ESE and SE. It ascends in a quasi-parabolic arc with a clockwise turn, exceeding NW at about 6000 meters, then going up at the almost constant direction of NW to NNW, and terminating at an altitude of 7000 meters. The mode profile of wind direction exhibits a more complex structure which can be distinguished in three altitude intervals: (1) Surface to 1500 meters, (2) 1500 to 4000 meters, (3) 4000 to 8000 meters. The general trend of the mode profile is a consistent turn from NE clockwise around the whole windrose back to ENE. In the lowest altitude layer (surface to 1500 meters) the mode profile swings back from NE to almost North (500-meter height), and then proceeds clockwise straight toward South (1500-meter height). There, the mode profile is joined by another mode branch, originating in SSE at the surface and advancing in a counterclockwise turn to about ESE, where it terminates at a 2500-meter altitude. The central branch of the mode profile continues at 1500 meters from SSE with a monotonous turn to West, reaching this azimuth at 3000 meters. From there, the central mode branch climbs, at constant direction, up to an elevation of 4000 meters. In the highest altitude layer (3) the mode profile splits at 4000 meters with one branch turning slightly back to West, while climbing to 8000 meters. The other mode branch turns further, from West clockwise toward NE, which azimuth is reached at a 5000-meter altitude. Finally, this mode branch turns back to NNE, climbing to the point of termination at an elevation of 8000 meters.

Annual Wind Direction Profiles at 15:00 Z (09:00 Local). The annual wind direction profiles during the morning hours at New Orleans again typically exhibit three different configurations in terms of ranges of altitude (Fig. 20). These three height ranges refer to the Surface Boundary Layer (up to 3000 meters), the middle troposphere region (3000 to 14,000 meters), and the tropopause stratospheric region (14 to 21 kilometers). For the lower two of these profile regions, the profile shapes resemble those of the seasonal, all-hour wind direction profiles of spring (Fig 1). The profile of mean direction starts at the surface at about East, and turns clockwise to SW which is attained at an elevation of 1000 meters. A steeper ascent of the mean profile turns it further until at 3000 meters an azimuth between WSW and West is being reached. From there, the directional mean profile remains within plus or minus ten degrees of West throughout the mid-troposphere, extending up to 14 kilometers. Through the tropopause, then, the directional mean profile turns still clockwise from West to NW (17 kilometers), then swings counterclockwise back to almost NNE where it terminates at a 21-kilometer altitude.

The mode wind profile within the surface boundary layer consists of two major branches and one minor branch. The two major branches originate at the surface at the directions of NE and about NW, whereas the minor branch starts at about South, and combines with the NE branch mode already at 500 meters. Both major mode branches (NE and NW) combine closely to West and at an elevation of 3000 meters. To reach this point of junction, the NE mode branch turns clockwise with a remarkable directional shear of 120 degrees for the lowest 500 meters of altitude. The NW mode branch takes, from the surface, a clockwise turn beyond North up to 500 meters, but then returns, with a directional zigzag pattern between WNW and West, to the junction point with the NE mode branch.

The mode profile of the middle troposphere, between 3000 and 14,000 meters, stays consistently close to West. At the upper boundary of this altitude region, the mode profile again splits into two branches. A western branch of the mode profile rises from 14 to 16 kilometers at an azimuth of straight West, then shifts to SW at 20 kilometers, and finally turns back to almost WNW at the termination point in a 21-kilometer altitude. At 18 kilometers, another sub-branch splits off from the western mode profile and turns from about WSW to almost South, which is reached at an elevation of 19 kilometers. The southeastern branch of the mode profile in the upper troposphere begins at 14 kilometers with a rapid turn from West through South towards East, which is attained within one straight stretch at 15 kilometers. From there on, the direction of this branch of the mode profile stays around East, with only one slight bulge toward ENE (17-kilometer height), and terminates at an elevation of 21 kilometers.

Annual Wind Direction Profiles at 18:00 to 21:00 Z (12:00 to 15:00 Local). The class of annual wind direction profiles of the noon and early afternoon hours evinces a relatively simple and clear structure, as presented in Figure 21. The directional profiles of this class show a noticeable similarity to the seasonal, all-hours profiles of spring (Fig. 1), particularly in the surface boundary region and in the middle troposphere. The mean direction profile starts at East on the surface, and turns rapidly clockwise to West within the first 2000 meters of altitude. From there on, the mean profile ascents in a flat, quasi-parabolic arc, gradually turning clockwise further towards North, which is reached at a height of about 17 kilometers.

The directional mode profile begins at the surface with two branches, the initial directions being South and NNW respectively. These two model branches join each other, and meet the mean profile as well, at an elevation of 2000 meters and at a western azimuth. The combined mode profile then rises at almost constant direction around 280 degrees with minor fluctuations, up to a height of 15 kilometers. At this point, the model profile again splits into two branches. The southern mode branch turns counterclockwise toward SSE, terminating at 17 kilometers. The northern mode branch turns from West (15-kilometer height) through North to almost East, also terminating at an elevation of 17 kilometers. The directional gradients of these two mode branches above 15 kilometers are nearly equally strong (120 degrees per 2000 meters for southern branch, 160 degrees per 2000 meters for northern branch.

V. CHARACTERISTICS OF WIND SPEED PROFILES

The wind speed profiles of New Orleans, Louisiana, which infer the mean of the scalar wind magnitudes as a function of altitude, are organized into three groups of presentation:

1. The seasonal profiles for all hours of the day (Fig. 22)

2. The monthly profiles for all hours of the day (Figs. 23, 24, 25, 26)

3. The annual profiles with subgroups of all hours of the day combined, and for four different times of the day (Fig. 27).

A. Seasonal Wind Speed Profiles

For the first overall orientation on the wind speed behavior at New Orleans the seasonal mean profiles for all hours of the day may be considered (Fig. 22). In general, the lowest wind speeds occur in summer and the highest ones during winter, at least within the troposphere. The maxima of the wind speeds for all four seasons occur at practically the same height of 12 kilometers, which is in the upper half of the troposphere. At this altitude, the maximum mean speed for summer is 25 meters per second, and in winter it rises to 60 meters per second. The mean wind speed at the surface is remarkably close for all four seasons, within the range of 9 to 12 meters per second. Again, at the lower boundary of the stratosphere, the four seasonal wind speed profiles meet within a narrow speed range, around 20 kilometers. There all four profiles cluster around 20 meters per second. At still higher altitudes, the summer and winter profiles reverse their predominance: The mean wind speed profile in summer advances to 30 meters per second at 22 kilometers, and the winter mean profile shows a receding trend. Also the spring profile goes back to 14 meters per second at this highest level on record. It appears remarkable that the mean wind speed profiles for winter and spring stay closely together through the whole altitude range from the surface to the lower stratosphere. The mean profile of fall stays about in the middle between the summer and winter (spring) profiles, and only above the tropopause joins the summer profile for an interval of altitude of about 3000 meters.

B. Monthly Wind Speed Profiles

The monthly mean wind speed profiles of New Orleans represent the monthly wind speed conditions for all hours of the day (Figs. 23, 24, 25, 26). The monthly wind speed plots are grouped in terms of seasons. The speed profiles of the spring months (March, April, May, Fig. 23) indicate a substantial dispersion about the seasonal mean profile (Fig. 22). Although the mean wind speeds at the surface are close to 10 meters per second for both the individual spring months and the spring season, only the profile of April peaks at the same speed value of 60 meters per second (altitude, 13 kilometers) as the seasonal profile does. During March, however, the peak wind speed rises to 83 meters per second at a height of 12 kilometers. In May, the peak of the mean wind speed profile attains only a value of 50 meters per second (altitude, 13 kilometers) which remains by 10 meters per second under the seasonal peak value. The dispersion of the peak values of the monthly mean profiles of spring is reflected in the trends of the individual total profiles themselves. Thus all mean wind speeds throughout the troposphere in May are the lowest of the spring season, and all mean wind speeds of March are the highest of that season. The mean wind speed profiles of the spring months terminate at an altitude of 19 kilometers. At this height, the mean wind speed value of April (21 meters per second) is close again to the seasonal mean value (23 meters per second). At the same ceiling altitude the May value is 11 meters per second below, and the March value is 12 meters per second above the seasonal mean value (23 meters per second).

The dynamics in the monthly mean wind speed profiles during summer (June, July, August, Fig. 24) are quite moderate, as could be expected. The mean wind speed values at the surface are almost uniquely 8 meters per second for both the individual summer months and the seasonal mean. The profile of August follows the profile of the summer season most closely, with a peak value of 26 meters per second (altitude, 12 kilometers) in both quoted profiles. The dispersion of the peak values in the other two summer months is less than 4 meters per second above (June) and below (July) the mean value of August (altitude, 13 kilometers). The mean wind speed values of June are the highest of the three summer months from the surface up to 16 kilometers, where this profile starts to coincide with the profile of July. The mean wind speed values of July are the lowest of the summer months from the surface to 14.5 kilometers. From this elevation up to an 18-kilometer height, the mean wide speeds of August are the lowest during the summer months, with a minimum of 9 meters per second at a 16-kilometer altitude (termination of profile). It appears remarkable that the mean wind speed profiles of both July and August, which terminate at 22 kilometers, jointly increase to 30 meters per second at this elevation, equaling the peak value at 13 kilometers (June). The tendency of these two profiles points toward still greater wind speeds at higher altitudes.

The monthly mean wind speed profiles during fall (September, October, November, Fig. 25) again exhibit a clear pattern of dispersion, with the profile of October being the central one, between the profiles of September (below) and November (above). In agreement with this rather symmetrical spacing in the wind speed dimension, the October profile coincides most closely with the seasonal mean profile (Fig. 22). The peak of the mean wind speed profiles of fall occurs during November, at a 13-kilometer altitude and with a speed value of 54.5 meters per second. The peak mean speed of September is nearly 20 meters per second below the November value (September peak, 35 meters per second; altitude, 12 kilometers). The lowest mean wind speed during fall, beyond the surface boundary layer, occurs during September at an 18-kilometer altitude. It has a magnitude (15 meters per second) which is still about 5 meters per second below the lowest mean speed in summer (August, 20 meters per second) at the same elevation (18 kilometers). Again, the three monthly profiles of fall are closely together at their terminating altitude of 18 kilometers, with the wind speed range being bound between 15 and 20 meters per second.

At the surface, the monthly mean profiles of fall start within the narrow range of 8 to 10 meters per second. After separating into the sequence of individual profiles of September (lowest), October (middle) and November (highest) at about 500 meters, the wind speed remains fairly steady within the speed range of 13 to 17 meters per second up to an altitude of 2000 meters, and in the case of September and October, even up to a height of 4000 meters.

Finally, the mean wind speed profiles for all hours of the day during the winter season (December, January, February, Fig. 26) present the features of a strongly dynamic windfield. Although the mean wind speed profile of the winter season (Fig. 22) somewhat exceeds the mean profile of the spring season up to the altitude of tropospheric wind speed maximum, the highest mean wind speed of any winter month is still 9 meters per second below the maximum mean speed of any spring month. During winter, the highest mean wind speed occurs during February, with $w_m = 74$ meters per second at a 12-kilometer altitude. The profiles of the winter months start at the surface with a mean wind speed of slightly below 10 meters per second, and increase fairly uniformly up to an altitude of 7000 meters (February: $w_m = 44.5$ meters per second). From this elevation upwards the profile of January falls back behind the other two months, and does not exceed 51 meters per second at 14 kilometers which is the profile maximum. From the elevation of the general maximum of the mean speeds at 12 kilometers, the wind speed profiles recede to 23 meters per second above the tropopause. At this height, the January profile cuts with a flatter gradient across the other two monthly profiles up to a 19-kilometer altitude, and terminates at 20 kilometers with the same wind speed value of 23 meters per second.

C. Annual Wind Speed Profiles

The annual mean wind speed profiles of New Orleans are presented (Fig. 27) for five different time periods of the day:

1. 03:00 Z (21:00 CST, local)
2. 06:00...09:00 Z (00:00...03:00 CST, local)
3. 15:00 Z (09:00 CST, local)
4. 18:00...21:00 Z (12:00...15:00 CST, local)
5. All hours of the day (periods 1...4 combined).

Remarkably, the wind speed profiles of the various time periods stay closely together, with the exception of two cases of profile deviation within two height layers of 7000-meter thickness. Thus, the profiles for 03:00 Z and 15:00 Z are practically identical with the "All Hours" profile. This implies the similarity of the wind speed patterns of late evening and the morning hours, with no or only limited influx of solar energy. This group of three similar mean profiles starts with about 10 meters per second at the surface, followed by a steep gradient to 15 meters per second wind speed at 500 meters (03:00 Z). From there upward, the wind speeds are nearly constant (at 15 meters per second) up to the elevation of 3000 meters. Above that height, the mean wind speed increase in this group of profiles is steady and almost linear. The maximum of the mean speed, w_{mm} = 45 meters per second, is attained at an elevation of 12 kilometers. Above this altitude of the maximum of the mean wind speed, the three profile types under discussion recede in a contour form of a concave parabolic arc to a mean speed of 20 meters per second at an altitude of 23 kilometers.

The 06:00...09:00 Z-profile rises from 6.5 meters per second at the surface to about 15 meters per second at 300 meters and above that altitude stays steadily between 15.5 and 17.5 meters per second mean speed to an elevation of 10 kilometers, where it terminates at 17 meters per second mean wind speed.

Finally, the 18:00...21:00 Z-profile very closely follows the "All Hours" profile to the height of 8000 meters. Above that elevation, this profile is shaped as a convex arc of parabola, with its maximum of the mean speed of 35.6 meters per second at 12 kilometers. Then the profile recedes to 22.5 meters per second at terminating height of 17 kilometers. At this elevation, the mean speed of this profile is again close to the mean speed value of the "All Hours" profile, with w_m = 25.3 meters per second.

VI. CONCLUSIONS

Statistical parameters of atmospheric physics as complex as wind profiles necessitate a gross concept for proper representation of their basic and prominent features. However, any such gross concept must not obscure the significant details of the parameter information as a consequence of rate of simplification which is eventually too high. It appears that the method of mode profiles of wind direction, as applied in the present investigation, proved its merits convincingly.

The mode profiles of the flow directions in the three-dimensional wind field at New Orleans evidence two characteristic features in comparison with the mean profiles. In the planetary boundary layer, i.e., generally up to an elevation of 2500 meters, and in the majority of the monthly wind direction profiles of all hours of the day, at least one pair of directional modes is discernible. The same finding applies to the annual direction profiles for the various observation periods of the day. Typically, these two directional modes start at the surface usually close to the azimuths of North and South. This same category of profiles also splits into multimodes above the level of 14 kilometers. During the summer months, the pattern of multimode profiles of wind direction becomes quite complex even in the middle troposphere. Recognizing these essential details of the directions of atmospheric flow proves the significance of the concept of modes versus the presentation of plain means.

Further, a distinguished status of August through November within the annual course is exhibited by the counterclockwise turn of the wind spiral. This contrast to the wind situations during the remainder of the year is most pronounced in August, when the wind direction in the mid-troposphere switches from easterly towards westerly azimuths.

Considering the mean profiles of scalar wind speed, the uniformity at low absolute speed magnitudes of the summer profiles is striking. In contrast, the mean speed profiles of the other three seasons show significant dispersion of the speed ranges for the individual months, with March producing the highest absolute speed magnitudes (maximally 83 meters per second at a 12-kilometer altitude). However, the annual wind speed profiles for the various time periods of the day again evidence a high degree of uniformity, with few exceptions of daily time periods of observation for which the data populations might be too limited for warranting an unbiased result.

APPENDIX

THE COMPUTATION OF THE MODE BY MACHINE METHODS

A. Introduction

While it is possible to determine the mode for a few frequency distributions by eyesight or subjectively, dealing with several hundreds of distributions may consume considerable time. Therefore, objective derivation by automatic computers may be quite desirable.

If only the class with the maximum frequency of a distribution is sought, determination by electronic computers is generally very simple. The problem loses its trivial status, if more than one mode appears and random fluctuation of the frequency distribution ought to be eliminated. Further complication arises if the element of frequency distribution follows a periodic scale such as the wind direction. The following scheme has been successfully used in the determination of the mode, as demonstrated in the preceding sections.

It is necessary to begin at a minimum value of the frequency distribution, not necessarily zero. Then the following classes in sequence are separated into three groups (Fig. 28):

1. Positive if significantly higher than the preceding class;

2. Negative if significantly lower than the preceding class;

3. Zero if neither of group 1 or 2.

We may characterize group 1 with plus, group 2 with minus and group 3 with zero.

Any other assignment of figures or symbols could be employed. The sequence of signs can now be used in order to determine the mode as explained later.

One more definition of the classification scheme is necessary. It is possible that a slow increase in frequency caused by the significance criteria introduced in the next section would render a sequence of zeros, which may contradict the intended classification. It is, therefore, necessary to check on the occurrence of two subsequent zeros the frequency of the class prior to the preceding one. With significance existing between these two, the second zero would then be converted into a plus. Thus, a sequence of zeros indicates then strictly a number of equal classes, while a slow increase (decrease) would then be indicated by the sequence of zero-plus (or zero-minus respectively), etc.

As the first entry employs the class with the minimum frequency, an automatic negative value can be assigned. The adjacent class can then be either zero or plus. This expedites the program for the first two classes. The following class needs then to go through the process indicated in the flow chart (Fig. 28).

If a periodic element is used, consideration must be given to closing the cycle.

B. Criterion of Significant Progress

The evaluation of the class sequence as outlined above renders the possibility to apply a significance criterion, which may have the following form for ϵ, the difference of the frequency between classes:

$$\epsilon = \epsilon_{(n,f,s)} = \frac{a}{\sqrt{N}\,\sqrt{f_i}} \; . \tag{1}$$

This means that ϵ should decrease proportionally to the square root of N according to the progression of the normal error law. Therefore, frequency distributions of large samples display significant positive (negative) progression already for a smaller increase in frequency than smaller samples, which seems reasonable.

It is further desirable to include a criterion discriminating the class frequency f_i. One may consider a directly proportional increase with f or $\sqrt{f}$. Then an increase from 4 to 5 percent would be more significant than from 25 to 26 percent. However, one would have to realize that suppression of unimportant modes is one of intended goals. By making ϵ proportional to f or $\sqrt{f}$, we would create significance for increase or decrease in the area of minimum frequency and insignificance in the area of maximum class frequency. In order to use f as a tool of suppression of minor modes, the inverse f or $\sqrt{f}$ must be used as indicated by equation (1).

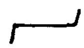
The constant a serves to adjust for the significance level S according to the confidence limit we may desire. A requirement of a 99 percent confidence limit needs a higher constant than a 95 percent confidence limit. Therefore, the constant depends upon the particular problem to be solved. It further may include consideration of the number of classes. Equation (1), therefore, expresses the relationship between the difference of the frequencies and the three variables on which the significance depends, namely the sample size, the confidence limit to be selected, and the parameter regulating the suppression of minor modes.

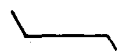
C. The Determination of the Mode

<u>The Mode From Class Symbols</u>. If group symbols for the sequence of classes are assigned, it is simple to determine the mode. We may simplify the sequence of group symbols by the definition that plus-zero-plus and minus-zero-minus transforms into plus-plus-plus or minus-minus-minus, respectively. This merely expresses that single zeros between plus or minus signs do not interrupt the progression sequence. This may be extended correspondingly to "+ 0 + 0 +" into "+ + + + +," etc. Then the following cases for the mode remain:

1. Plus-minus with frequency curve 

2. Plus-zero ... zero-minus with frequency curve 

3. Plus-zero ... zero-plus with frequency curve 

4. Minus-zero ... zero-minus with frequency curve 

It is obvious that the mode appears at the plus in case 1. It symbolizes a peak in the frequency distribution, which by definition is the mode.

The second case represents a platform, and the mode should be placed at the middle of the classes including the plus preceding the sequence of zeros. By conversion of the single zero embedded into plus or minus as defined above, case 2 must contain at least two zeros.

Cases 3 and 4 are similar to each other only with opposite signs. They must be treated alike; otherwise the definition of the mode would depend on the follow upof the class sequence for analysis (whether the data are analyzed clockwise or counterclockwise for a periodic system like the wind direction).

Thus, case 3 places the mode at the plus preceding the first zero, while in case 4 the mode emerges at the last zero before the negative sign. This rule places the mode into the same class irrespective of the direction of analysis, as readily can be seen.

Sequence of Modes. After the modes have been determined, as described in the previous section, it may be desirable to combine modes which are less than two classes apart.

This may depend upon the frequency of the class between modes and the relative relation between the respective modes. If $mode_1 \gg mode_2$, then $mode_1$ is the major mode and $mode_2$ may be neglected; if $mode_1 \ll mode_2$, then $mode_1$ may be omitted. Hereby the significance of $mode_1$ over $mode_2$ can be determined in similar fashion as indicated in equation (1).

This leaves the case in which $mode_1$ is approximately $mode_2$. It may be defined that the two modes shall be considered as one, if the class between proves within a certain percentage of $mode_1$ or $mode_2$. This may be determined independently of equation (1) or can be included into it by affixing the constant a of equation (1). If the frequency in the class between the two modes is small enough, then both modes may be accepted.

Determination of a Refined Mode. The preceding discussions took one class frequency alone into consideration. It is customary [7] to adjust the mode by including adjacent classes, thus accounting for asymmetric conditions of the frequency distribution. This can be applied in like manner after determination of a preliminary mode as described above.

$$\text{Mode} = m_p + \frac{f_a - f_b}{f_a + f_b} \cdot \frac{c}{2} . \qquad (2)$$

Hereby, m_p denotes the preliminary mode (e. g., central value of modal class), f_a is the frequency of the class (or classes) above the modal group, and f_b the frequency below. The letter "c" stands for the size of the class interval.

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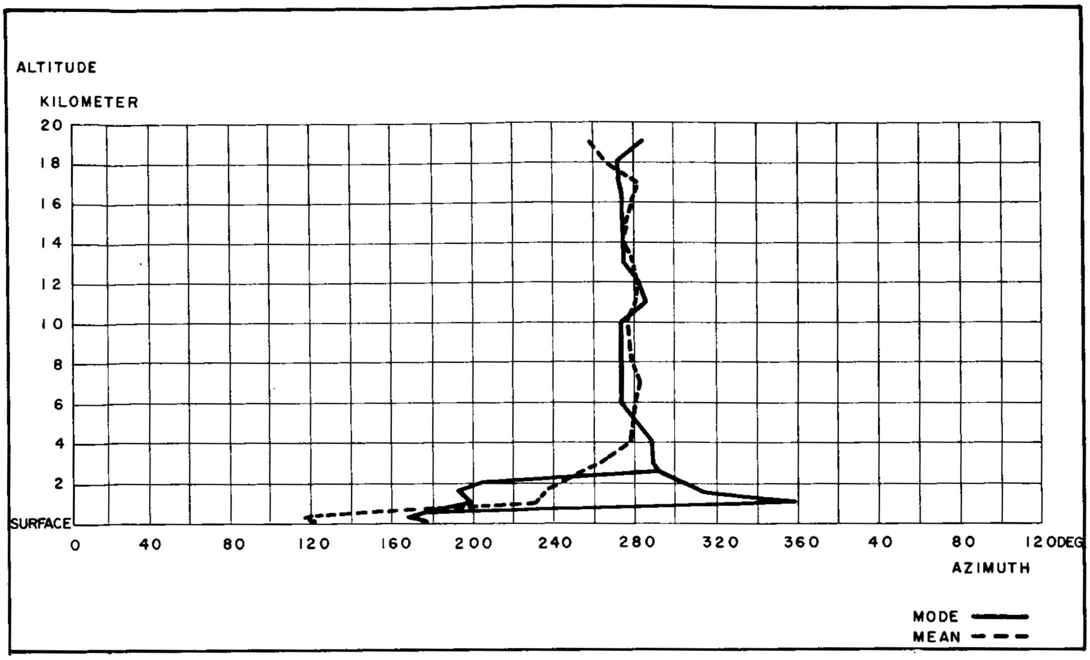


FIGURE 1. SEASONAL WIND-DIRECTION PROFILES: SPRING - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

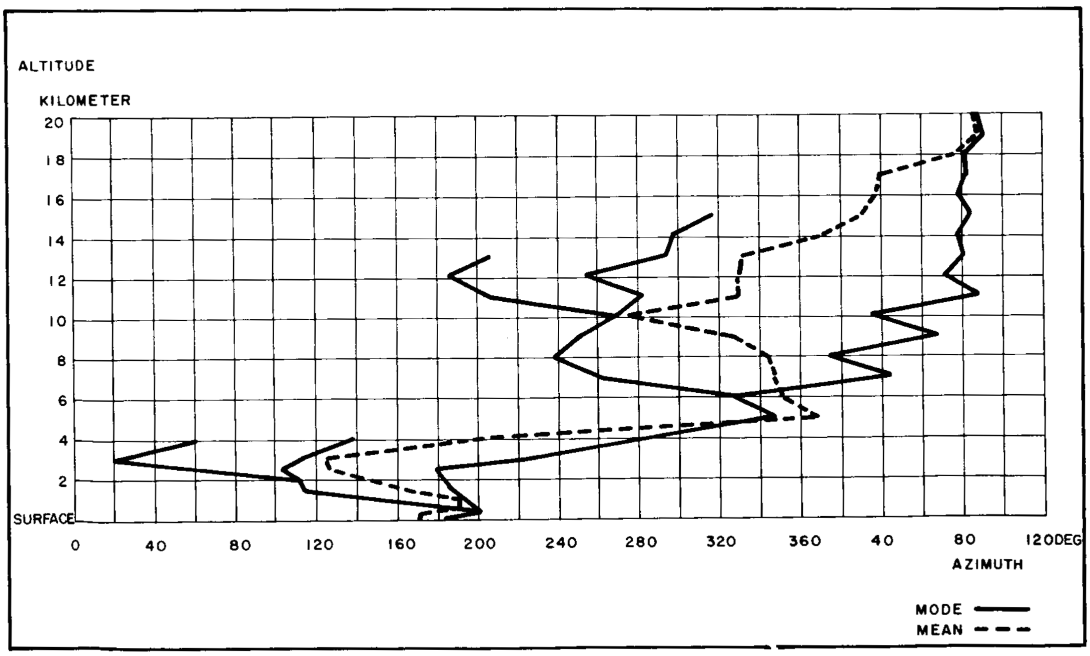


FIGURE 2. SEASONAL WIND-DIRECTION PROFILES: SUMMER - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

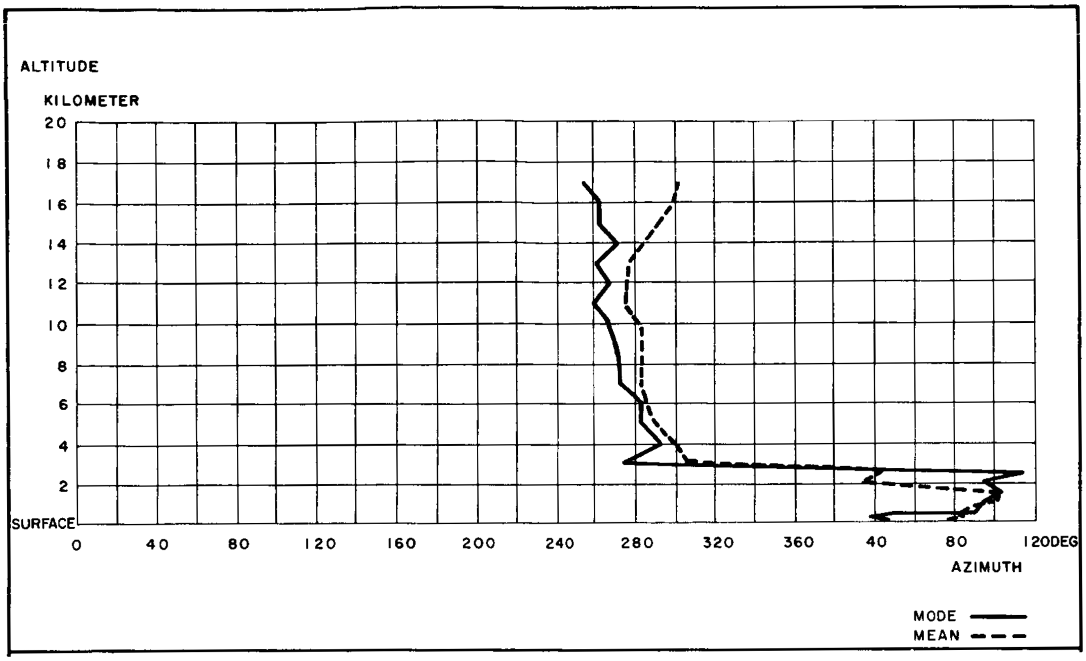


FIGURE 3. SEASONAL WIND-DIRECTION PROFILES: FALL - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

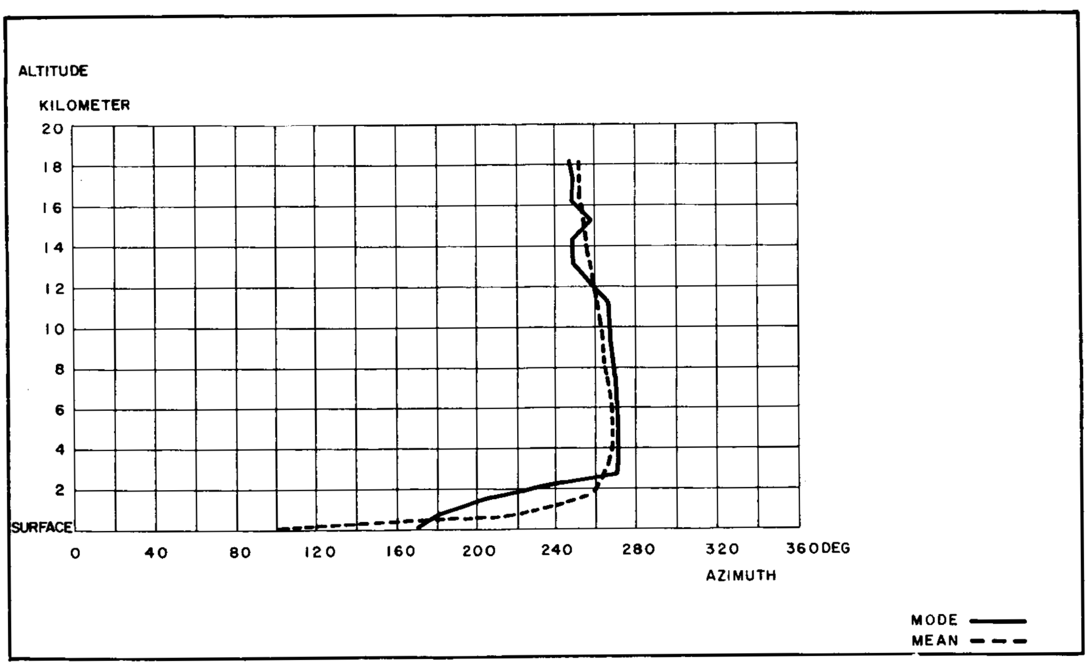


FIGURE 4. SEASONAL WIND-DIRECTION PROFILES: WINTER - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

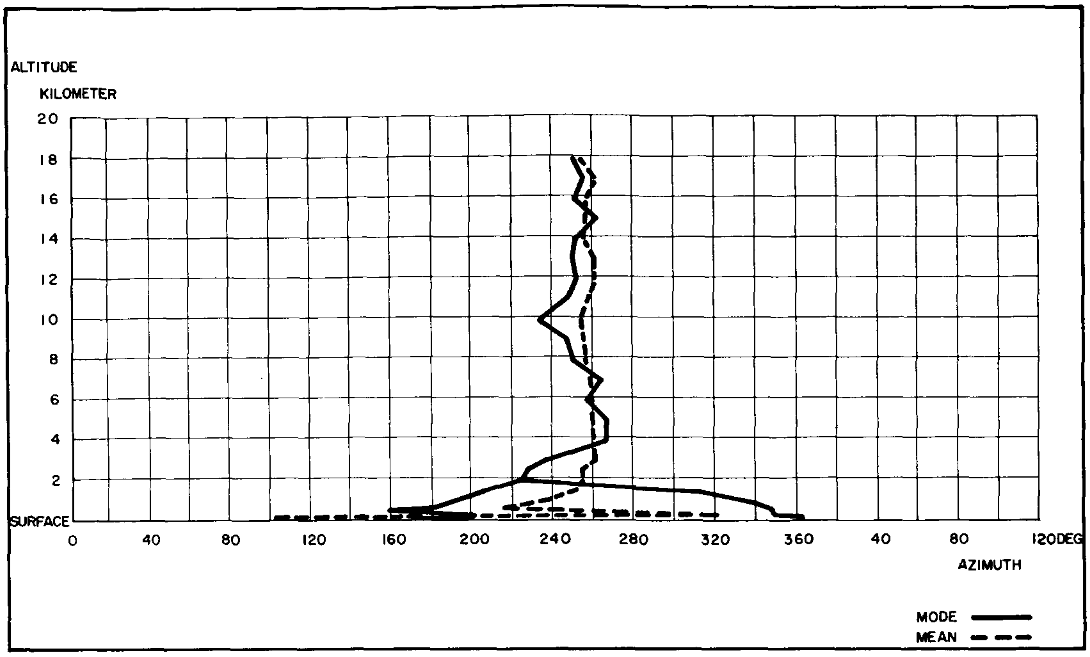


FIGURE 5. MONTHLY WIND-DIRECTION PROFILES: JANUARY - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

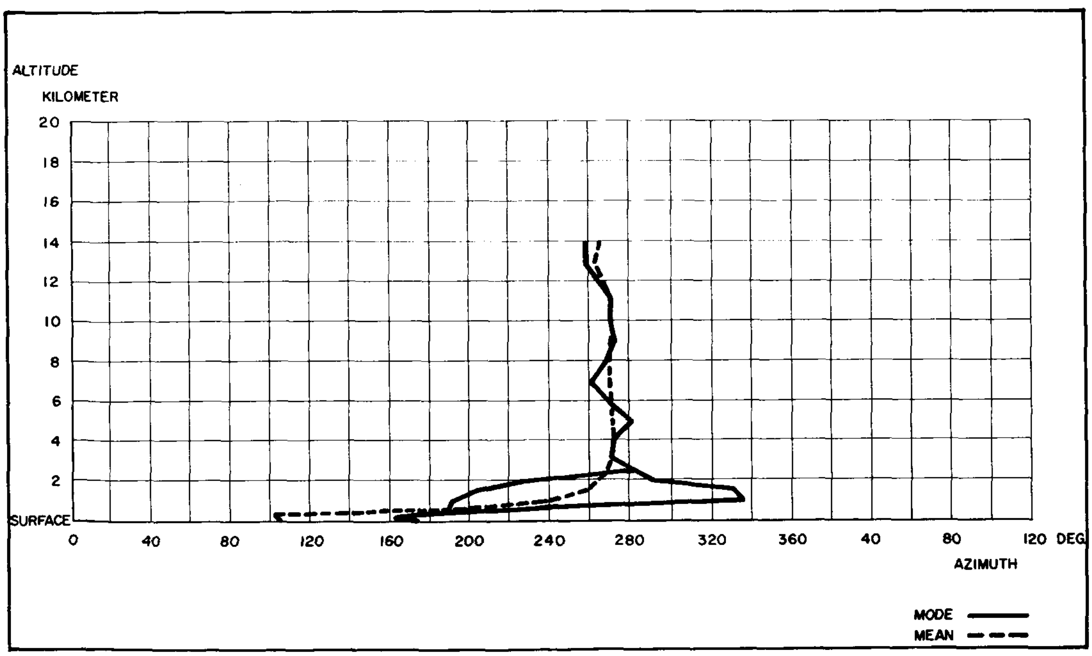


FIGURE 6. MONTHLY WIND-DIRECTION PROFILES: FEBRUARY - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

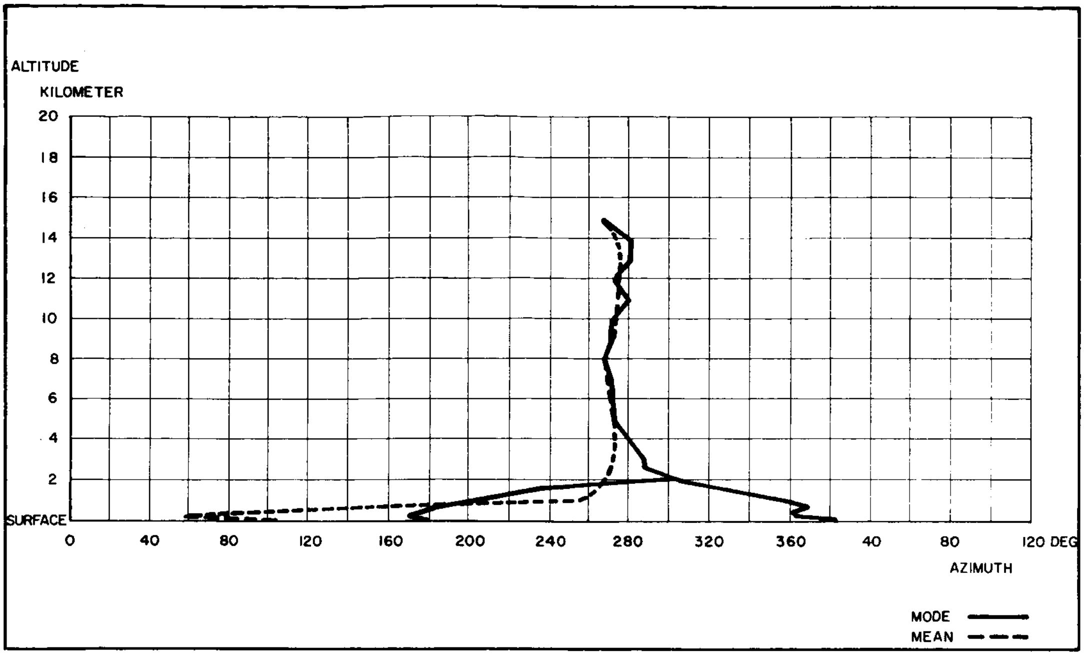


FIGURE 7. MONTHLY WIND-DIRECTION PROFILES: MARCH - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

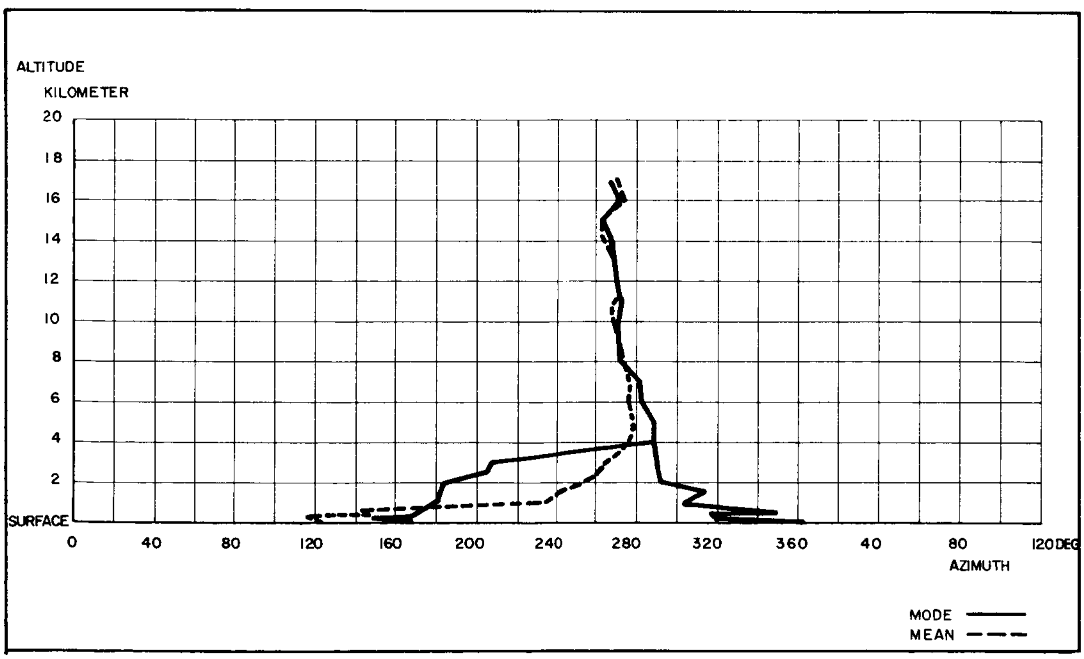


FIGURE 8. MONTHLY WIND-DIRECTION PROFILES: APRIL - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

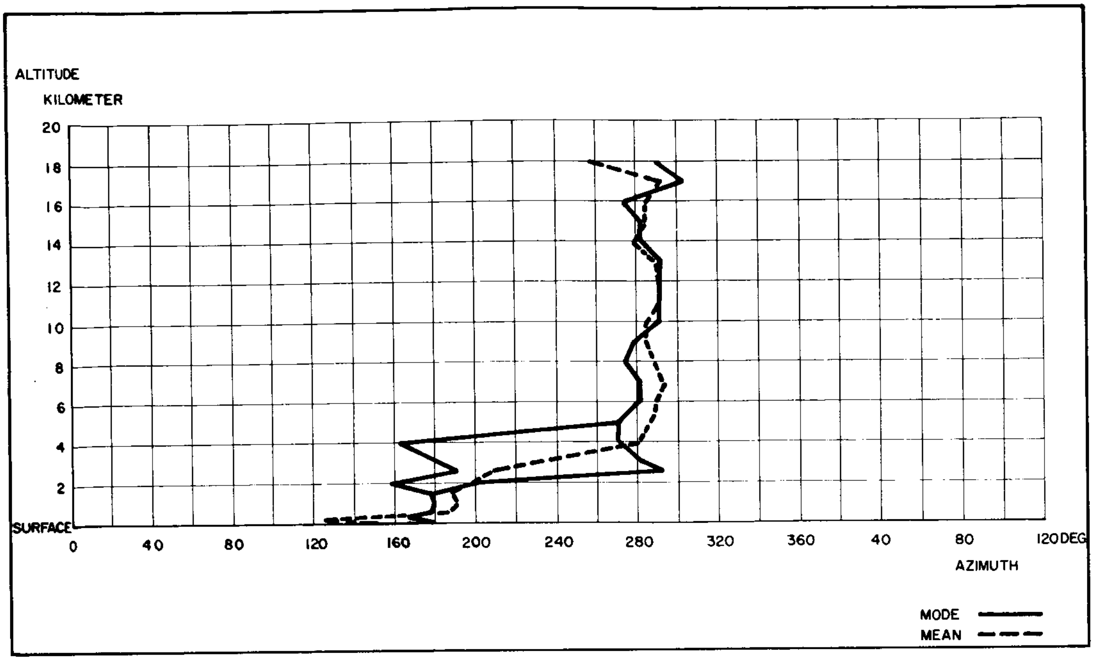


FIGURE 9. MONTHLY WIND-DIRECTION PROFILES: MAY - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

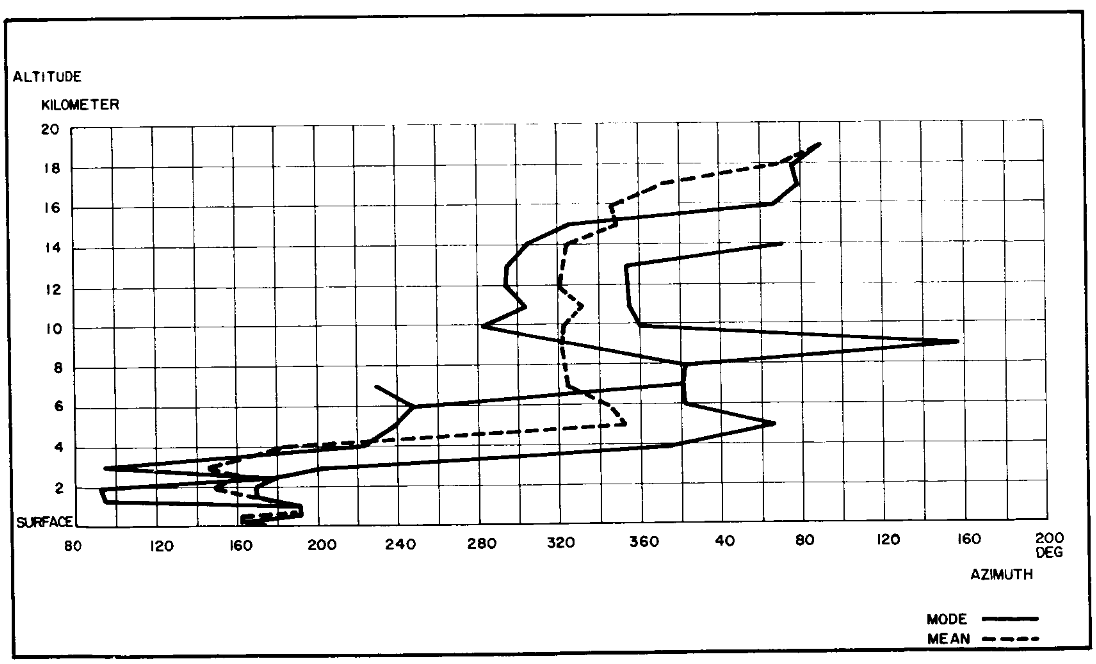


FIGURE 10. MONTHLY WIND-DIRECTION PROFILES: JUNE - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

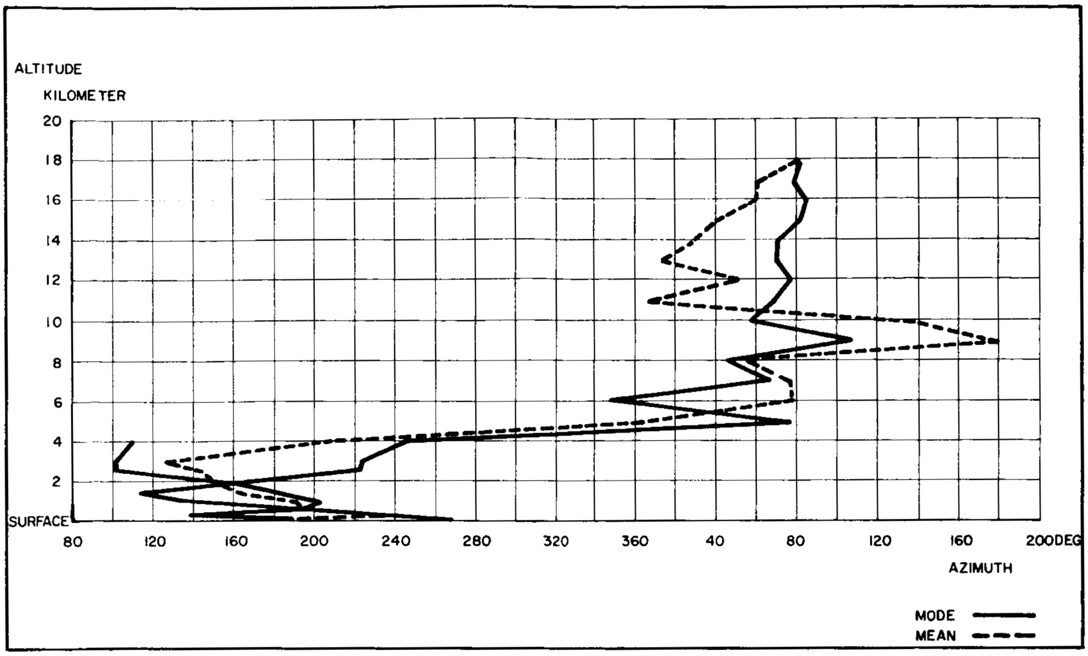


FIGURE 11. MONTHLY WIND-DIRECTION PROFILES: JULY - ALL HOURS.
NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

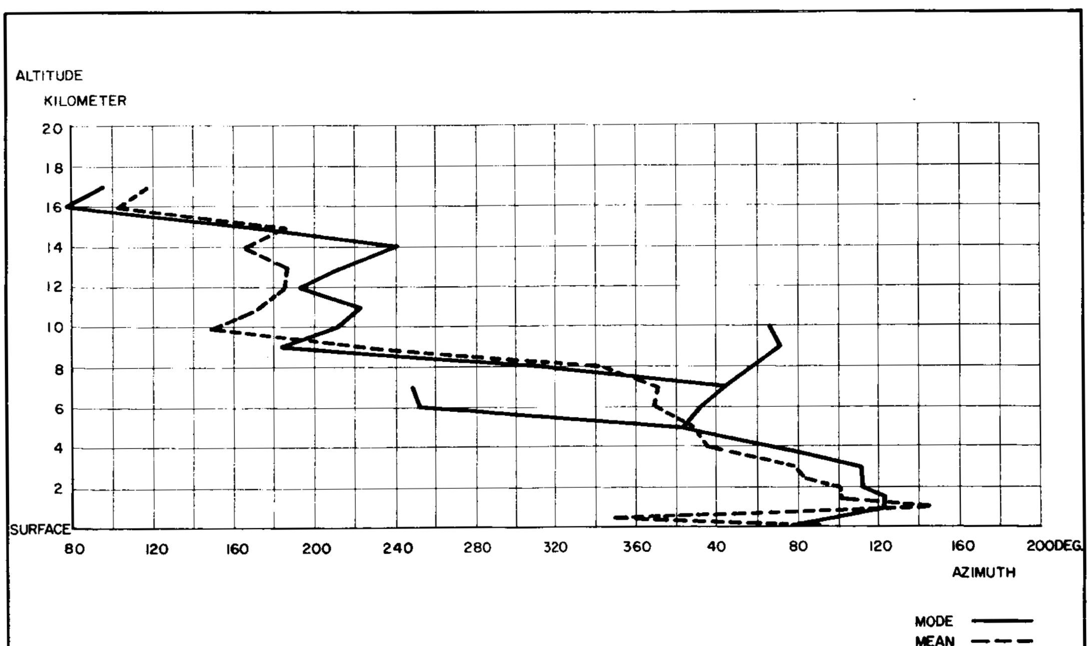


FIGURE 12. MONTHLY WIND-DIRECTION PROFILES: AUGUST - ALL HOURS.
NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

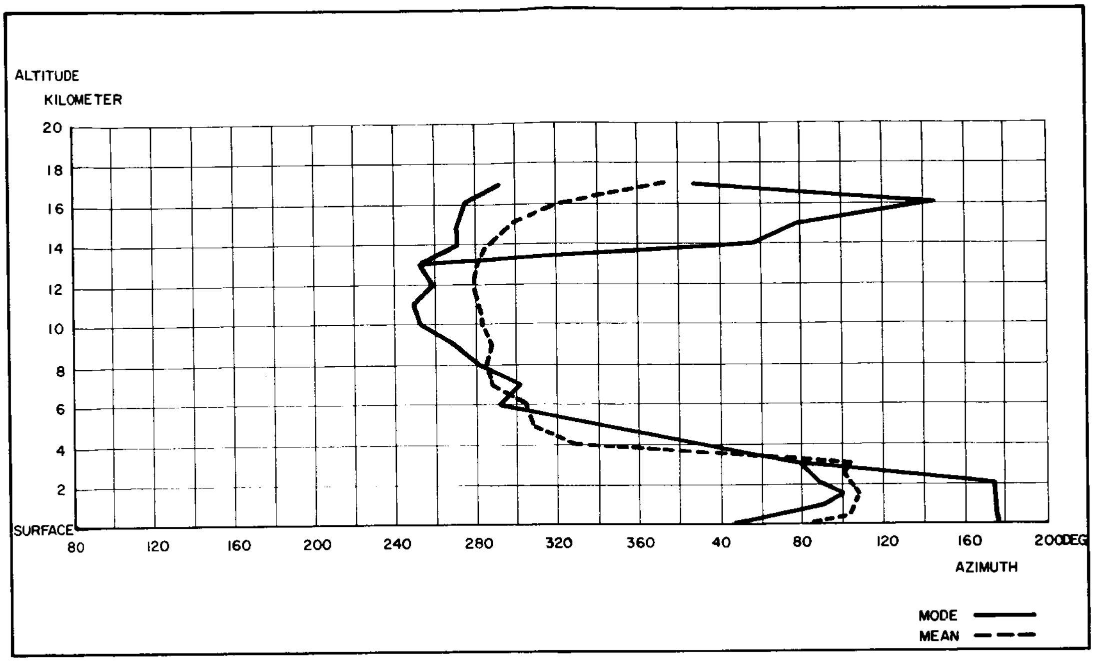


FIGURE 13. MONTHLY WIND-DIRECTION PROFILES: SEPTEMBER - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

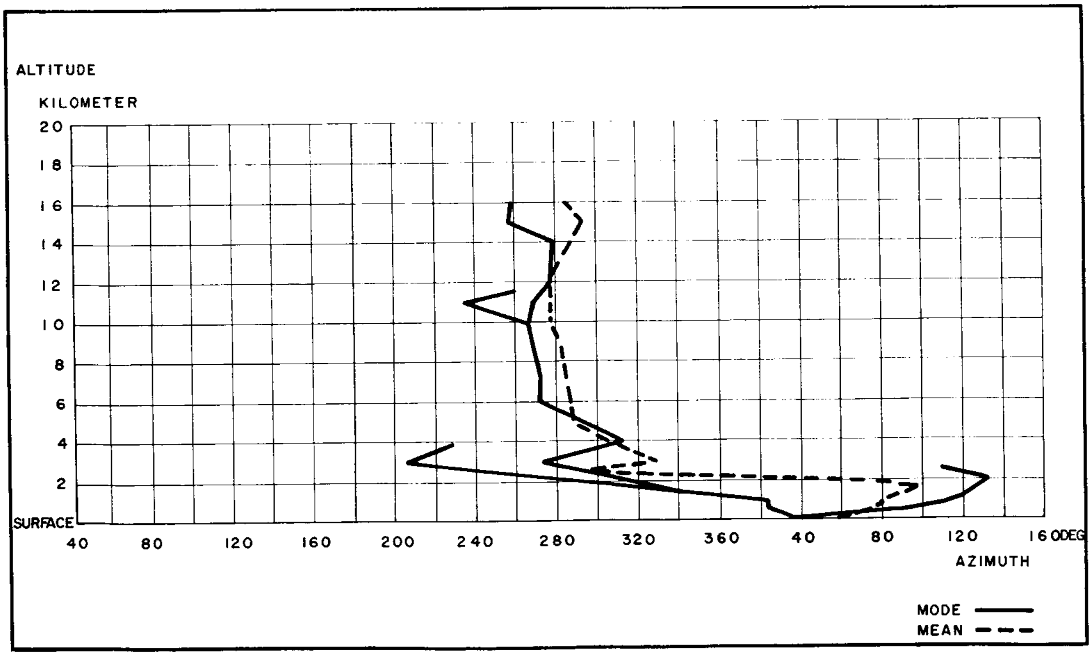


FIGURE 14. MONTHLY WIND-DIRECTION PROFILES: OCTOBER - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

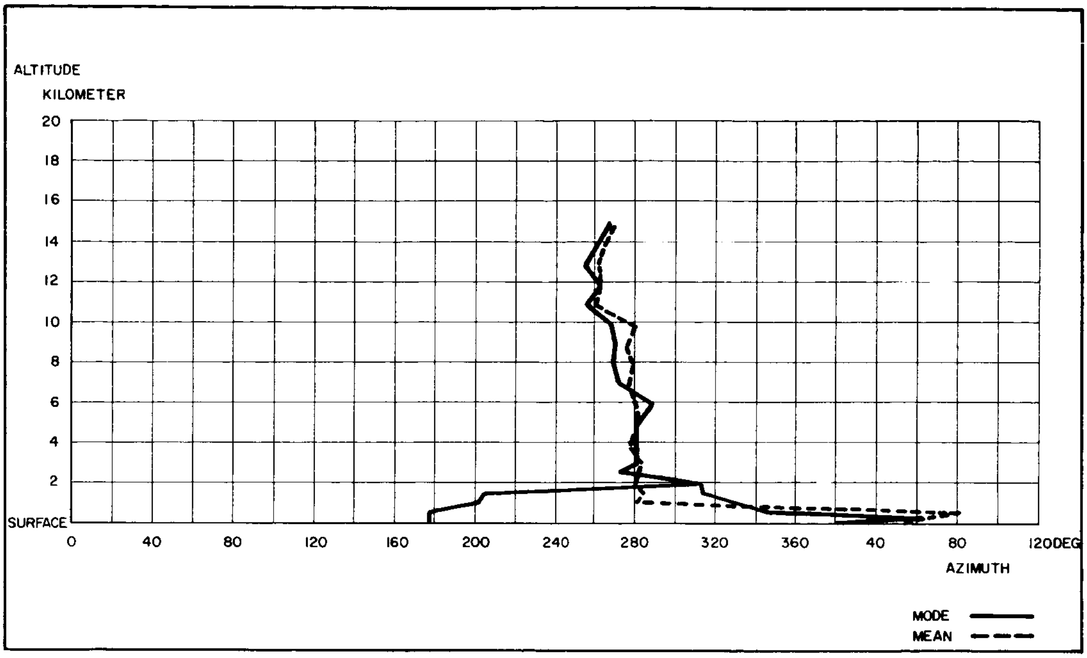


FIGURE 15. MONTHLY WIND-DIRECTION PROFILES: NOVEMBER - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

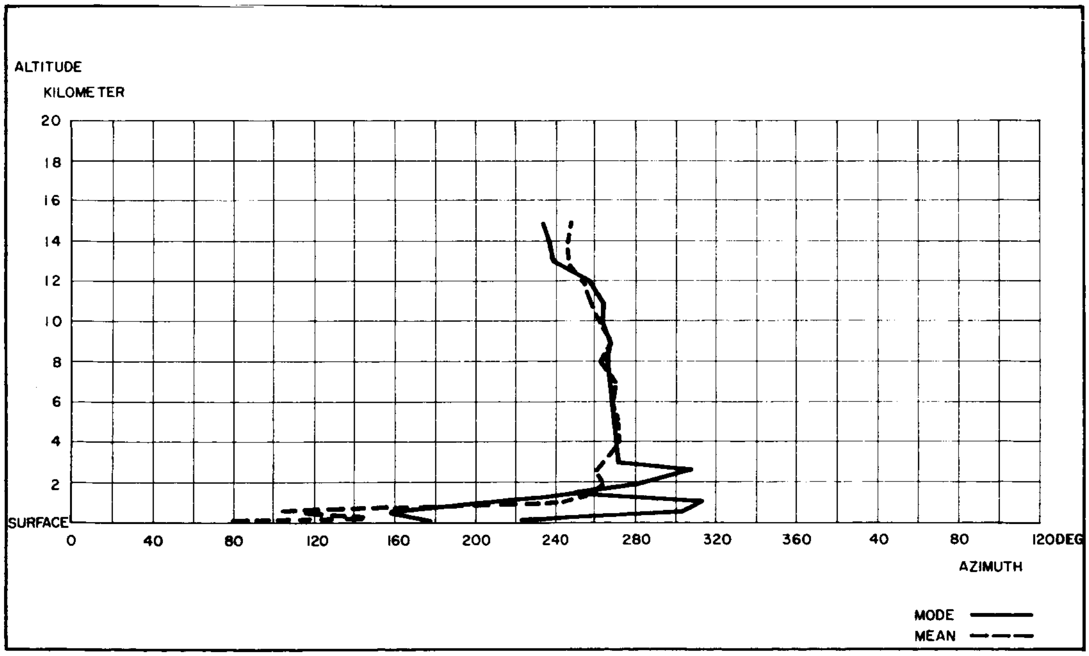


FIGURE 16. MONTHLY WIND-DIRECTION PROFILES: DECEMBER - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

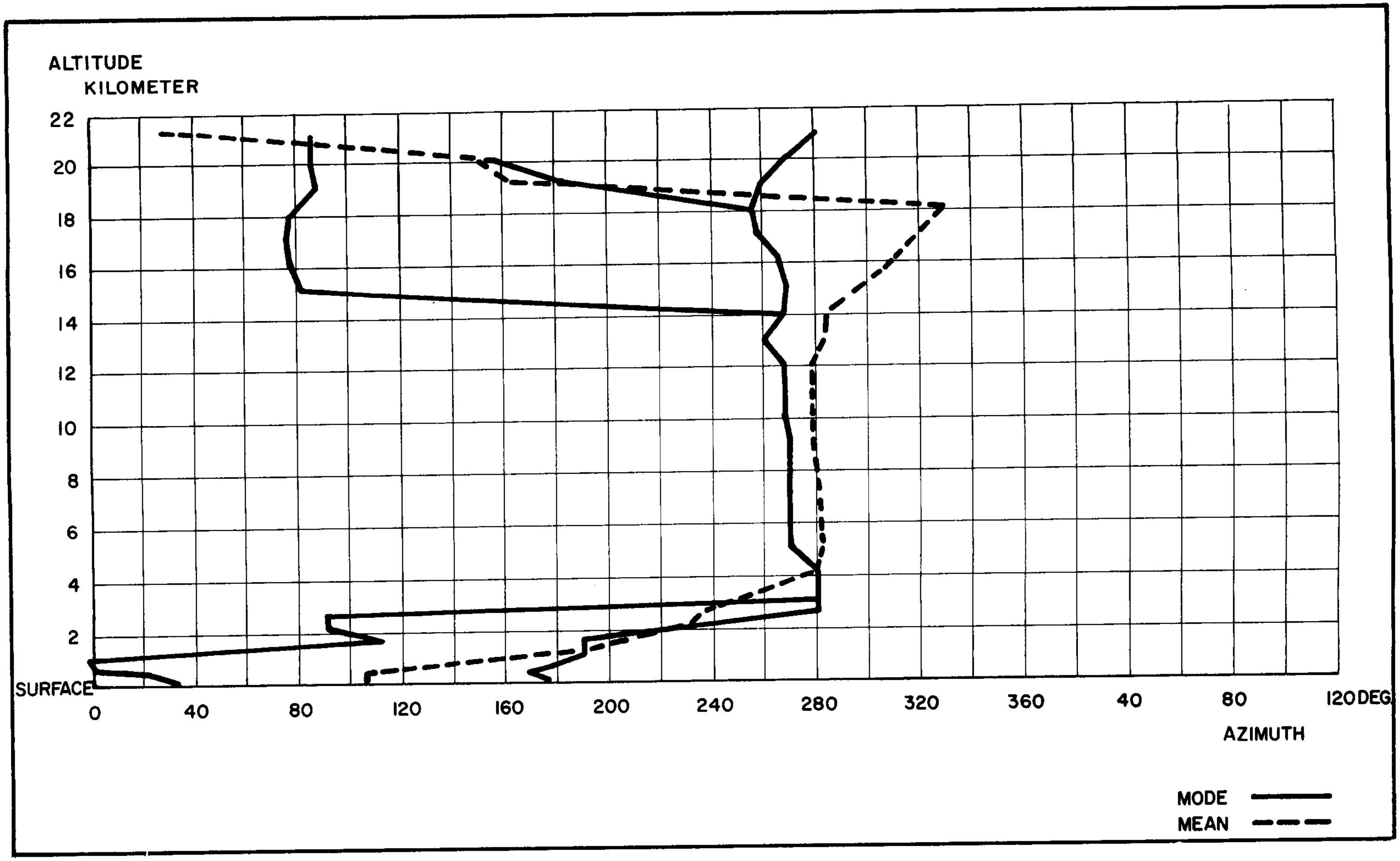


FIGURE 17. ANNUAL WIND-DIRECTION PROFILES: ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: JANUARY 1949-DECEMBER 1959

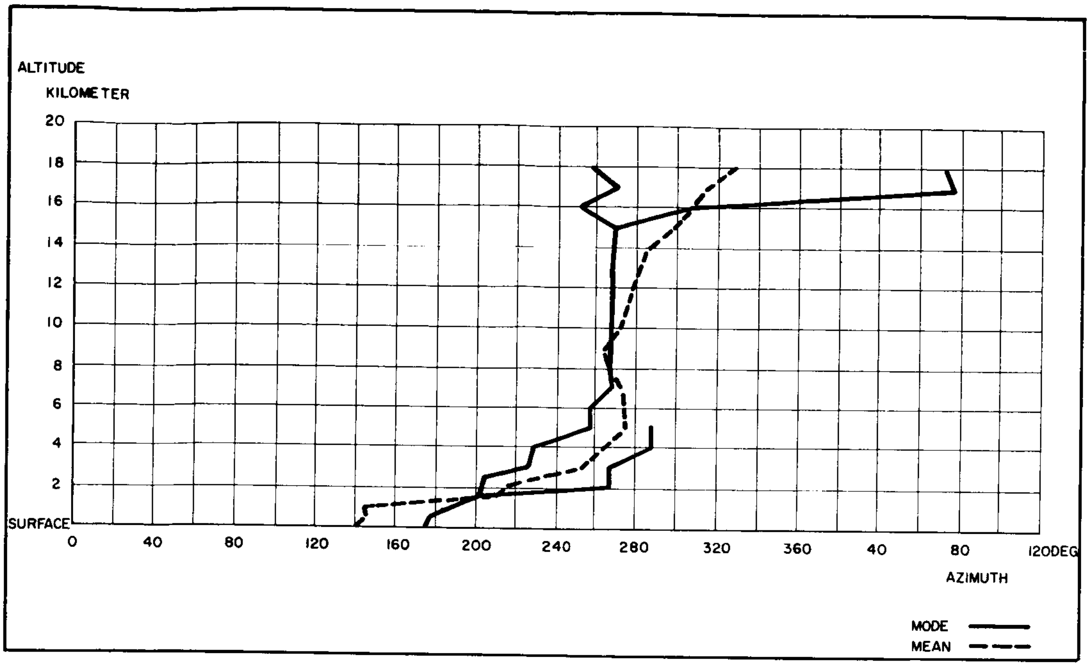


FIGURE 18. ANNUAL WIND-DIRECTION PROFILES: 03:00Z (21:00 CST, LOCAL). NEW ORLEANS, LOUISIANA, DATA PERIOD: JANUARY 1949-AUGUST 1950

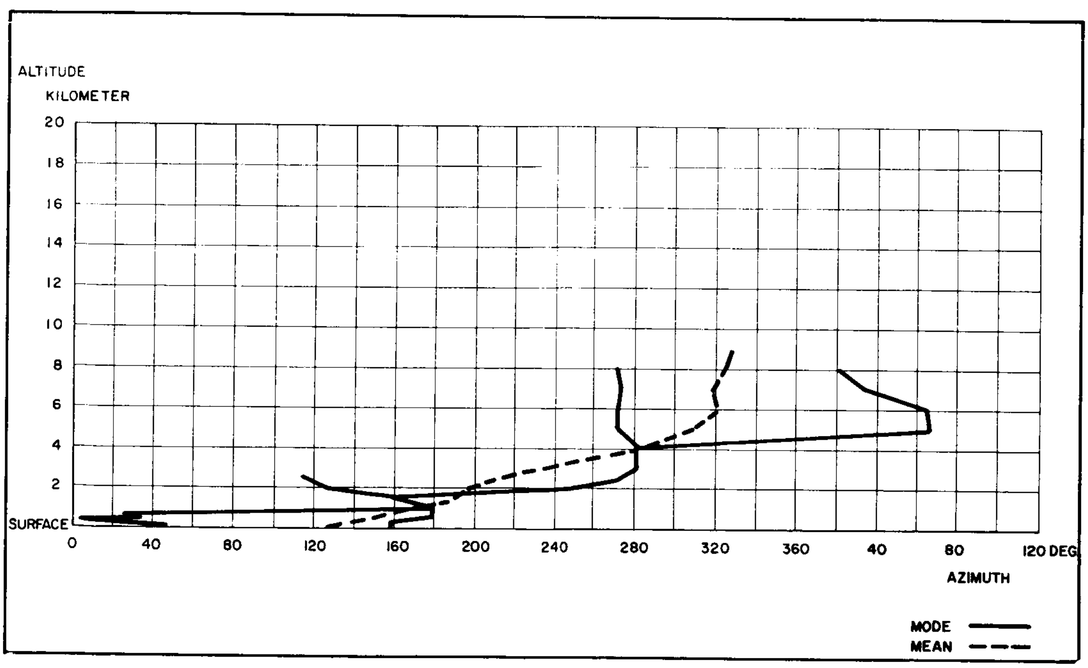


FIGURE 19. ANNUAL WIND-DIRECTION PROFILES: 06:00. . . 09:00Z (00:00. . . 03:00 CST, LOCAL). NEW ORLEANS, LOUISIANA, DATA PERIOD: JANUARY 1949-DECEMBER 1959

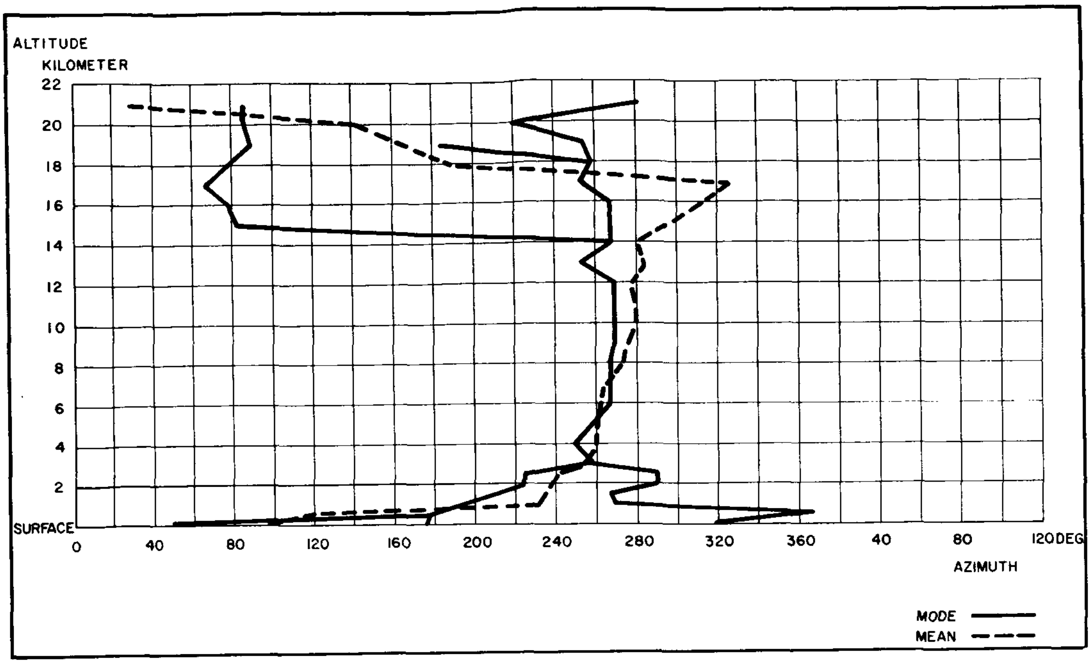


FIGURE 20. ANNUAL WIND-DIRECTION PROFILES: 15:00Z (09:00 CST, LOCAL). NEW ORLEANS, LOUISIANA, DATA PERIOD: JANUARY 1949-AUGUST 1950

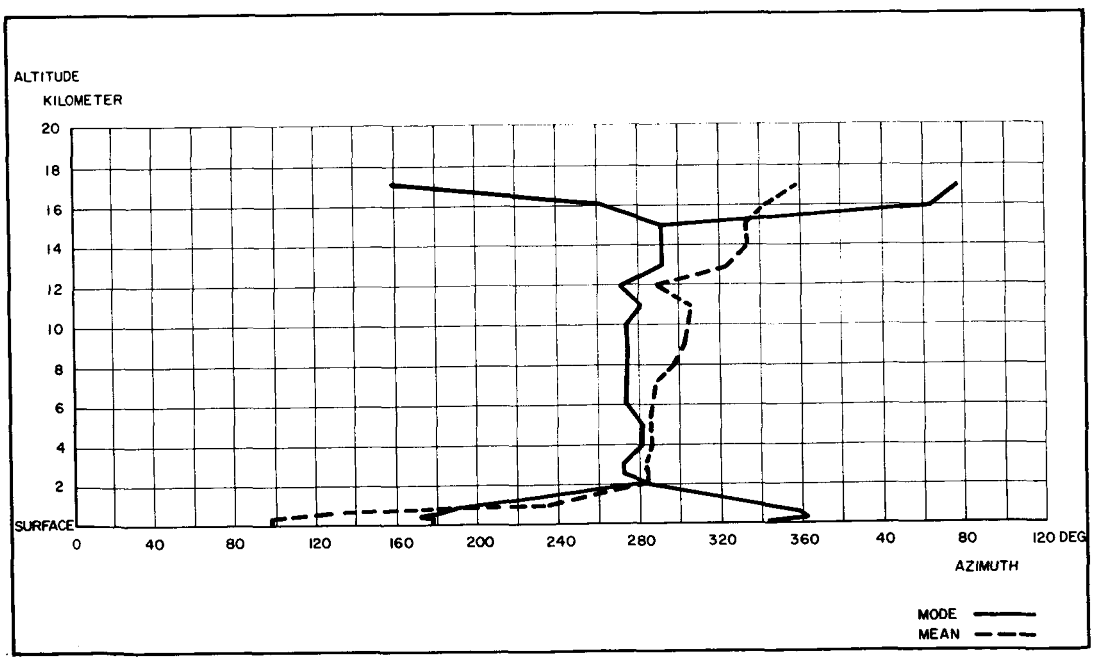


FIGURE 21. ANNUAL WIND-DIRECTION PROFILES: 18:00...21:00Z (12:00...15:00 CST, LOCAL). NEW ORLEANS, LOUISIANA, DATA PERIOD: JANUARY 1949-DECEMBER 1959

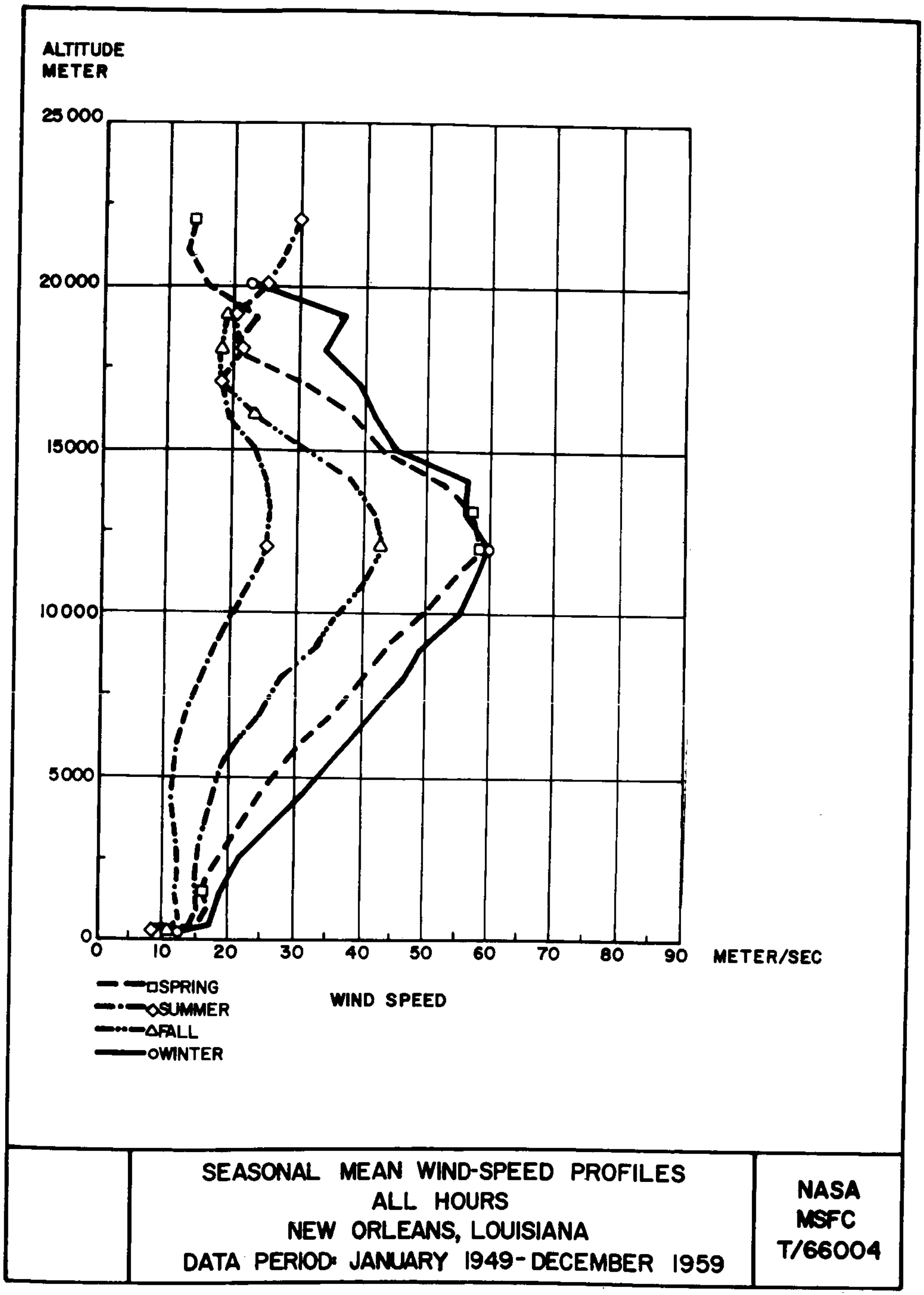


FIGURE 22. SEASONAL MEAN WIND-SPEED PROFILES: ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: JANUARY 1949-DECEMBER 1959

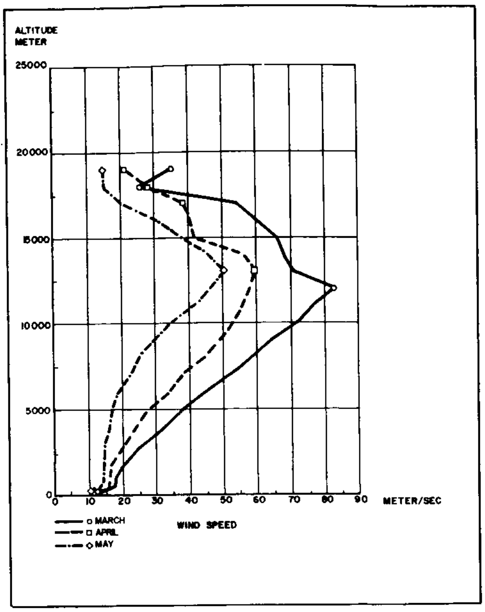


FIGURE 23. MONTHLY MEAN WIND-SPEED PROFILES: SPRING - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

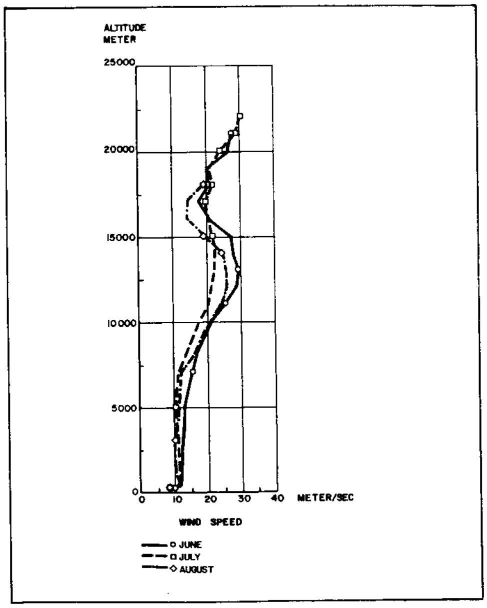


FIGURE 24. MONTHLY MEAN WIND-SPEED PROFILES: SUMMER - ALL HOURS. NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

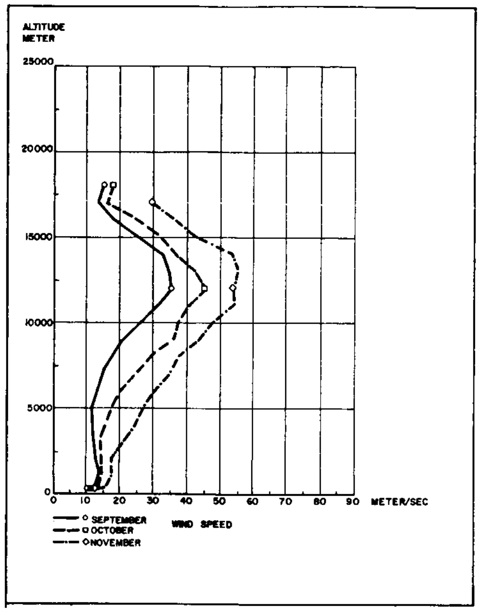


FIGURE 25. MONTHLY MEAN WIND-SPEED PROFILES: FALL - ALL HOURS.
NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

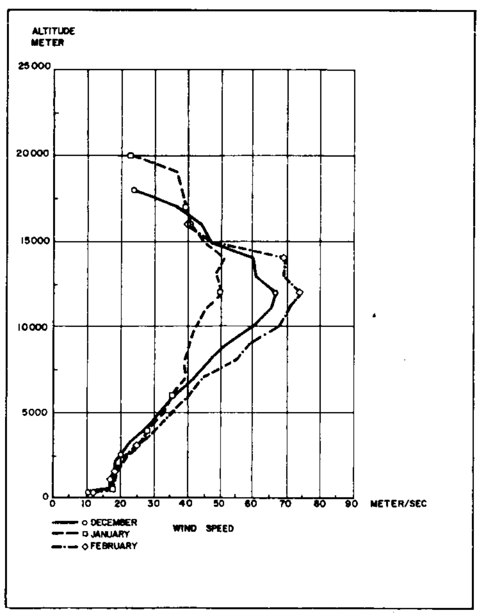


FIGURE 26. MONTHLY MEAN WIND-SPEED PROFILES: WINTER - ALL HOURS.
NEW ORLEANS, LOUISIANA, DATA PERIOD: 1949-1959

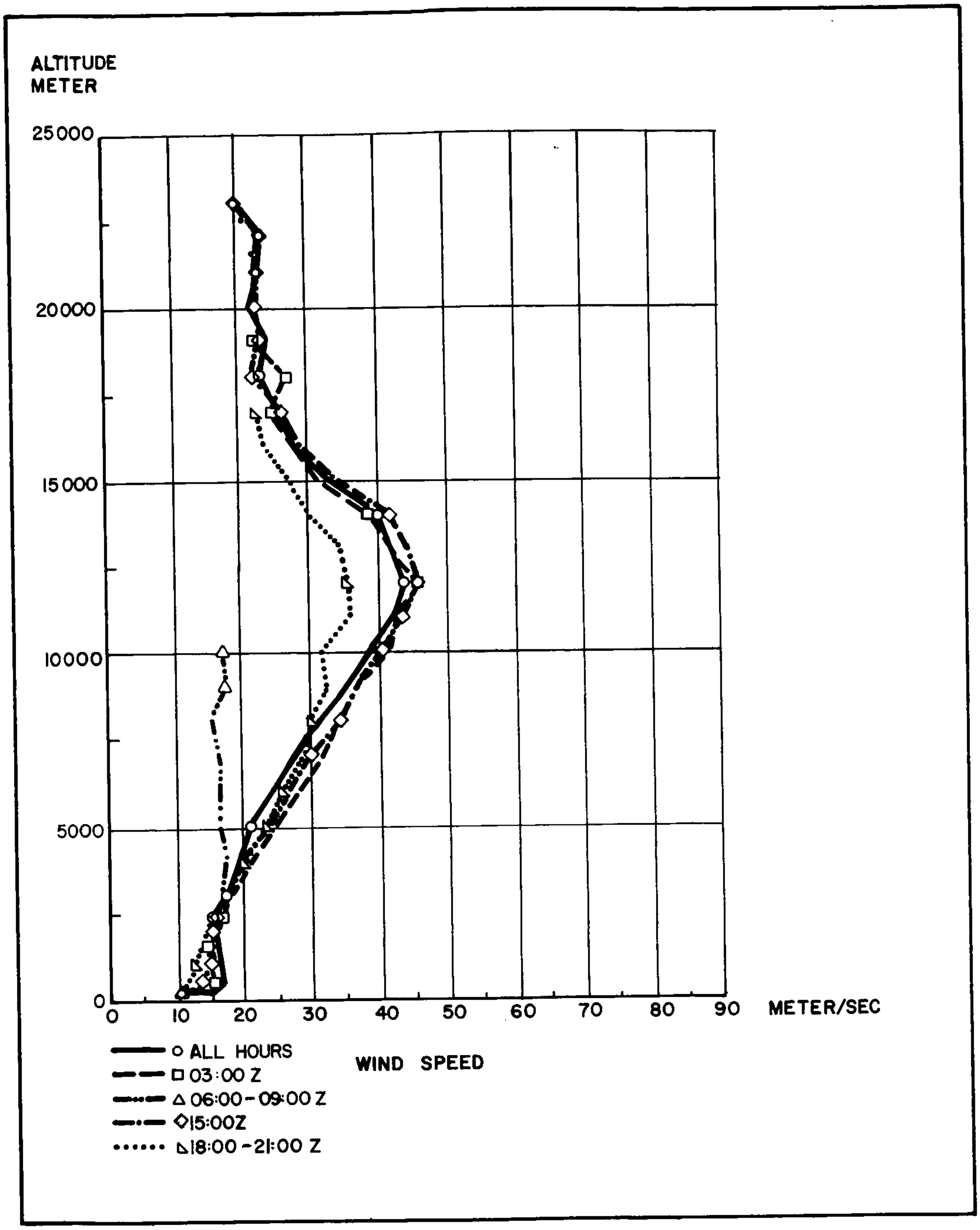
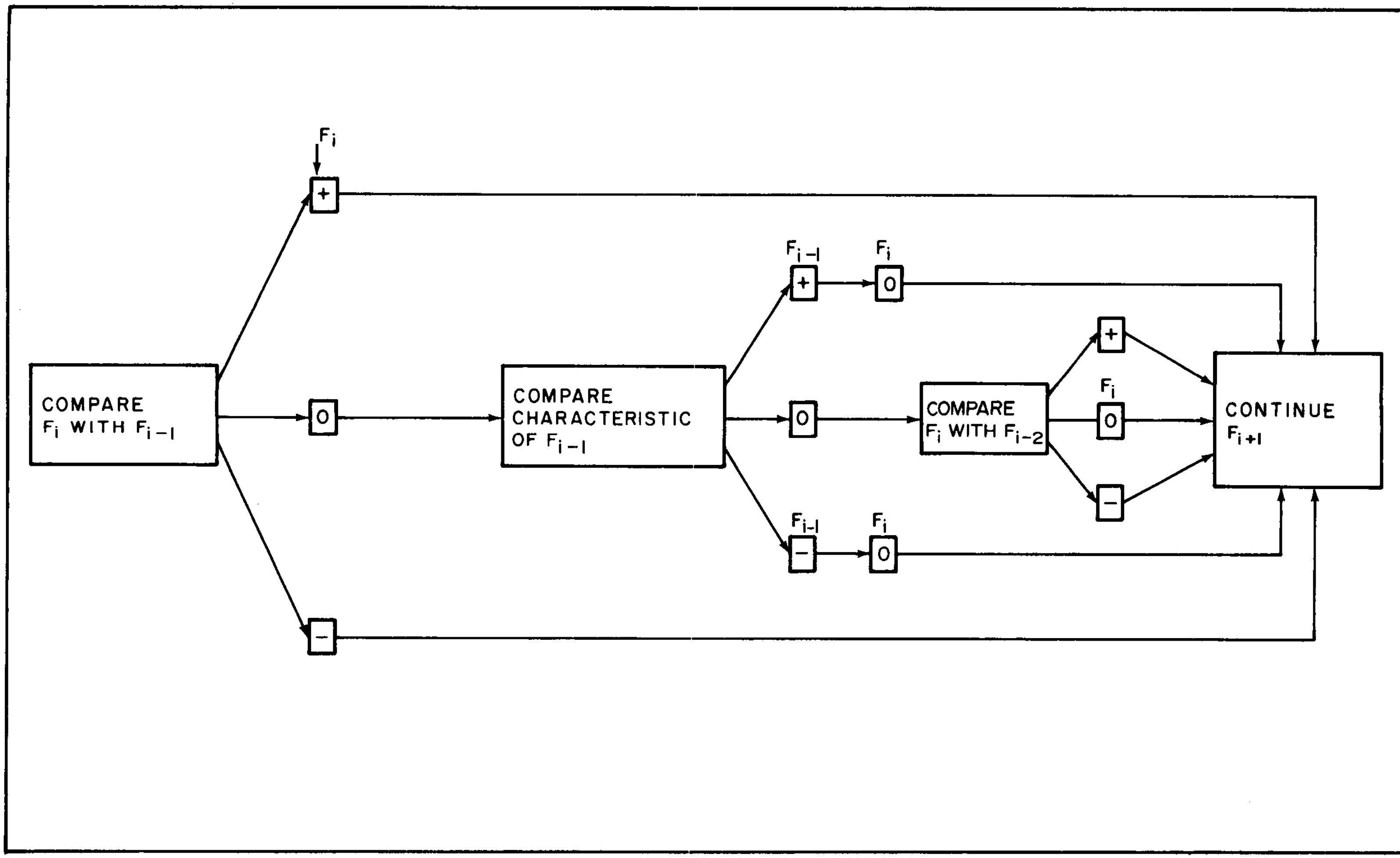


FIGURE 27. ANNUAL MEAN WIND-SPEED PROFILES: FIVE DAILY TIME-PERIODS. NEW ORLEANS, LOUISIANA, DATA PERIOD: JANUARY 1949-DECEMBER 1959



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The prominent climatological features of the tropospheric wind field at New Orleans, Louisiana, have been analyzed in terms of wind direction and wind speed. For the purpose of appraising the physical properties of the acoustical far field at the Mississippi Test Facility within the adjacent environment of New Orleans, the directional parameter of the wind field was investigated in particular depth. Besides the mean profiles of wind direction, the mode profiles were derived by means of a new method developed by Dr. Essenwanger, which is presented in an appendix to the report.

Both the wind direction profiles, in terms of mean and mode, and the mean scalar wind speed profiles are presented for the whole year, the four seasons, and the individual months. Also, the annual profiles of various time periods of the day are provided for both wind direction and wind speed.

Multimodes of the wind direction profiles appear typical in the planetary boundary layer (approximately surface to 2500-meter height), mostly with surface azimuths of North and South. During the summer months, the middle troposphere is covered by a remarkably complex pattern of multimodal wind direction profiles. Also, the annual wind direction profiles of various time periods of the day show
(Continued on page 49)

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13. ABSTRACT (Continued)

at least a bimodal configuration in the upper troposphere, above the jetstream level.

The mean wind speed profiles exhibit the typical tropospheric pattern with the speed maximum at the subtropical jetstream level of about 12 kilometers. These monthly profiles indicate a systematic dispersion of speed magnitudes, increasing toward spring. The maximum of the mean wind speed at New Orleans, Louisiana, occurs during the period of March, with a value of 83 meters per second, and at a height of 12 kilometers. However, the mean speed profiles of the summer months show remarkable uniformity, with considerably lower wind speed magnitudes, not exceeding a maximum value of 30 meters per second (13-kilometer altitude).